THE EFFECT OF LIQUID SMOKED FLAVOURINGS AND WOOD SMOKE ON THE QUALITY OF SMOKED MACKEREL FILLETS DURING CHILLED STORAGE

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ABTRACT

This study was undertaken to evaluate the effects of liquid smoked flavourings and wood smoke on the sensory, color, texture, and lipid stability of smoked mackerel fillets for four weeks chilled storage. Fish fillets were smoked by two methods: (1) immersed in brine (1:1) containing 100 g/L NaCl at 0-5 °C for 3 hours, allowed to drain at room temperature (~20 °C) for 2 hours and smoked directly with wood smoke in a smoking chamber at 25 °C for 3 hours; (2) immersed in brine (1:1) containing 5 mL/L commercial liquid smoke flavourings and 60 g/L NaCl for 16 hours at 0-5 °C then dried at 25 °C for 2 hours in an oven. Smoked samples were then vacuum packed and stored chilled at -1 °C for one week, followed by 4±1°C for three weeks. The quality changes in sensory, color, texture, and lipid stability were observed after 0, 1, 2, 3 and 4 weeks of storage. The results showed that, smoked mackerel using commercial liquid smoked flavourings was higher in rancid flavour, lightness, redness, and yellowness but had less bitter odour and was softer than the wood smoked mackerel. The lipid oxidation was higher after the wood smoke process but was however rather stable during the chilled storage. In contrast, lipid oxidation in the liquid smoked products increased significantly during chilled storage.

***Keywords**: Atlantic mackerel (Scomber scombrus), color, liquid smoked flavouring, lipid quality, sensory, texture, wood smoke*

I. INTRODUCTION

Smoking has been used for the preservation of food for centuries. Smoking gives the special color and flavour to the food [1], [8] and extends its shelf-life via the effects of dehydration, antimicrobial and antioxidant of the smoke compounds [1], [18]. Smoking also changes the texture of product [23]. The way to produce smoked food varies among different producers within one country, and the whole world. The quality of smoked fish is affected by raw material [7], salting method, brining concentration [1], [12], [22], processing conditions [8], composition of smoke [25], smoking method [6], smoke agents [24] and storage conditions.

Depending on the way smoke gets into products, smoking can be categorized accordingly: the traditional technique – where the smoke is formed directly by burning chips or sawdust from firm wood in the oven [25], [26]; or new technique - by using an electric field acting on the ionised smoke particles, which quickens the smoke deposition or by using commercial liquid smoke flavourings [8], [16]. Furthermore, smoking can be defined as hot smoking, warm smoking or cold smoking depending on the smoking temperature [8], [20], [26]. Cold smoking has only one basic function which is applying smoke to the product while the hot smoking has the function of applying heat and cooks the product [13]. It is therefore not necessary to cook hot smoked fish before consumption because it is a ready-to-eat food.

Commercial liquid smoke flavourings have several advantages over traditional smoking (wood smoke) procedures such as hygienic handling practiced during its preparation [17], much cheaper and less taxing on the environment [19]. Liquid smoke flavourings are also free of harmful compounds such as

polycyclic aromatic hydrocarbons (PAHs) [10] since PAHs are removed through the refining process. Using liquid smoke reduces the contamination of the final product with PAHs due to release of gaseous smoke. Moreover, smoke flavourings have different composition and can be combined to obtain products with very different organoleptic qualities.

In the seafood market, the smoking sector plays an important role. Since the 1990s, the consumption of smoked fish has increased, and smoked salmon is the most consumed product followed by smoked trout and herring [6]. Salmon is the most popular species, but the price of smoked salmon has increased considerably which makes it more difficult for people to purchase it.

Finding out whether one can use a cheaper species instead of salmon, such as smoked mackerel which has a similar flavour, texture, lipid content etc. as salmon is necessary. The mackerel is a fatty fish, it is considered one of the healthier fish because it is rich in omega-3 fatty acids and an excellent source of selenium, niacin, and vitamins B6 and B12. Mackerel is a valuable pelagic fish and most of the catch is for human consumption.

In the present study, the quality of smoked mackerel was studied to gain better understanding of the influence of different smoking methods on the quality of smoked products and would offer prospects for quality improvement of smoked products in Vietnam. The objectives of this project are therefore to determine the quality (sensory attributes, physical properties, and lipid quality) changes of smoked mackerel using wood smoke and commercial liquid smoke flavourings, during chilled storage.

II. MATERIAL AND METHODS

2.1 Raw material

Frozen Atlantic mackerel (Scomber scombrus) was used in this study. The material was harvested by Purse Seine in the South-East of Iceland. The mackerels were beheaded and gutted then kept at -1.2 °C. The temperature of raw material when landed was -0.9 °C and after packaging was 3.5 °C. Raw material was frozen without glazing in 16-kg blocks in an automatic plate freezer then stored at -18 °C for 6 months before processing. The experiments were carried out at MATIS laboratories in Reykjavik, Iceland.

2.2 Smoking agents

The smoking agents used were fireplace wood and commercial liquid smoke flavouring agent (SMOKEZ CLASSIC 5116, Red Arrow International, US). Concentrated aqueous solution of natural smoke flavours produced by controlled pyrolysis of mixed hardwoods with a food grade emulsifier added. The chemical properties of SMOKEZ CLASSIC 5116: pH: 2.5 - 3.5; total acidity (as acetic): 10.5 – 12.0 %; smoke flavour compounds: 13.0 – 20.0 mg/ml; carbonyls: 16.0 – 20.0 %; density (avg): 1.13 kg/L. The physical properties: clear, brown liquid with characteristic hardwood smoke aroma.

2.3 Salt and Packaging material

Suprasel salt (25kg Net) (AkzoNobel A/S Company, Denmark with ISO 9001 certified) and the vacuum bag (polyamide – PA) was supplied by the PMT Company, Iceland was used in this study.

2.4 Chemicals

All chemicals used in this study were of analytical grade and obtained from Sigma Aldrich (Steinheim, Germany).

2.5 Processing and sampling

Prior to processing, frozen mackerels were thawed in air at 0-5 °C for 17 hours. After filleting and washing with water at 4 °C, the fillets were divided in two groups. Group W was immersed in brine (1:1) containing 100 g/L NaCl at 0-5 °C for 3 hours, allowed to drain at room temperature (~20 °C) for 2 hours and smoked directly with wood smoke in a smoking chamber at 25 °C for 3 hours. Group L was immersed in brine (1:1) containing 5 mL/L commercial liquid smoke flavourings and 60 g/L NaCl at 0-5 °C for 16 hours, then dried at 25 °C (the same temperature in the smoking chamber) for 2 hours in an oven with air circulation. After smoking, both groups

were cooled at 0-5 °C for 1 hour and vacuum packed and stored at -1 °C for one week. The temperature was then increased to 4 °C and stored further for three weeks. Experimental analysis was performed on the arrival of the raw material, after smoking and after 1, 2, 3 and 4 weeks of storage for evaluation of sensory, color, texture, free fatty acid (FFA), peroxide value (PV) and thiobarbituric acid reactive substances (TBARS).

2.6 Analysis Methods

2.6.1 Sensory evaluation.

Sensory panels: Generic descriptive analysis (GDA) was used to assess thawed and smoked mackerel fillets. Eleven panelists, all trained according to international standards including detection and recognition of tastes and odours, trained in the use of scales and in the development and use of descriptors, participated in the sensory evaluation. The panel was trained in recognition of sensory characteristics of the samples and describing the intensity of each attribute for a given sample using an unstructured scale (from 0 to 100%).

Evaluation: Each attribute, as shown in Table 1 for fresh mackerel fillets and in Table 2 for smoked mackerel fillets was evaluated by every panelist in one whole fillet on a 100-point line scale anchored by the opposites 'none' to 'much'. The panelists evaluated each sample for each sampling day in triplicate while seated in separate booths under normal light in the sensory evaluation laboratory. Panelists used a computerized system for direct recording data. The fresh fish was cooked, and the smoked mackerel fillets were cut into thin pieces, and each portion placed in a small aluminum box.

Table 1. Quantitative descriptive analysis of fresh mackerel fillets.

sensory attribute	short name	scale	definition
ODOUR			
fresh oil	O-oil	none || much	Fresh fishoil odour
metallic	O-metallic	none || much	Metallic odour
sweet	O-sweet	none || much	Sweet odour
mouldy	O-mouldy	none || much	Mouldy odour
butiric acid	O-butiric	none || much	Butiric acid, smelly feet
rancid	O-rancid	none || much	Rancid odour
FLAVOUR			
fresh oil	F-oil	none || much	Fresh fishoil flavour
metallic	F-metallic	none || much	Metallic flavour
sweet	F-sweet	none || much	Sweet flavour
acidic	F-acidic	none || much	Acidic, sour flavour
mouldy	F-mouldy	none || much	Mouldy flavour
bitter	F-bitter	none || much	Bitter flavour
rancid	F-rancid	none || much	Rancid flavour
TEXTURE			
soft	T-soft	firm || soft	Softness in first bite
juicy	T-juicy	dry || juicy	Dry: draws liquid from mouth. Juicy: releases liquid when chewn
tender	T-tender	tough || tender	Tenderness when chewn
mushy	T-mushy	none || much	Mushy, porridge like texture
sticky	T-sticky	none || much	Glues together teeth when biting the fish.

Table 2. Quantitative description analysis of smoked mackerel fillets.

sensory attribute	short name	scale	definition
ODOUR			
butiric acid	O-butiric	none || much	butiric acid, smelly feet
rancid	O-rancid	none || much	rancid odour
spoilage sour	O- sour	none || much	spoilage sour odour
TMA	O-TMA	none || much	TMA odour (trimethylamine)
spoilage	O-spoilage	none || much	other spoilage odour, describe in comment line
FLAVOUR			
bitter	F-bitter	none || much	bitter flavour
rancid	F-rancid	none || much	rancid flavour
spoilage sour	F- sour	none || much	spoilage sour flavour
TMA	F-TMA	none || much	TMA flavour (trimethylamine)
spoilage	F-spoilage	none || much	other spoilage flavour describe in comment line

2.6.2 Physical Analysis.

Color.

The intensity of the flesh color was measured with a Minolta Chroma Meter CR-400 (Minolta, Osaka, Japan) using the CIE Lab system. The instrument recorded the L value, lightness on the scale of 0 to 100 from black to white; a value, (+) red or (-) green; b value, (+) yellow or (-) blue. The color was measured above the lateral line at five positions, from the head towards the tail of each fillet.

Texture.

Warner-Bratzler shear blade (type HDP/BS) was applied on fillet in each fish. The samples were of equal size, 2.0 cm in diameter and 1.5 cm in thickness above the lateral line close to the head. A v-shaped blade with a thickness of 3.20 mm, height of 125 mm and width of 70 mm was assembled to the TA.XT2i Texture Analyses. The maximum peak force in Newton required to shear through the sample was recorded as shear force.

2.6.3 Chemical Analysis.

Lipid content.

Total lipids (TL) were extracted from 25 g samples (80±1% water) with methanol/chloroform/0.88 % KCl (aq) (at 1/1/0.5, v/v/v) according to [4]. The lipid content was determined gravimetrically, and the results were expressed as grams lipid per 100 g wet muscle.

Free fatty acids.

Free fatty acids (FFA) were determined according to method from Lowry and Tinsley (1976) [15] with a modification made by Bernardez *et al*. [3]. 3 mL of the lower phase resulting from lipid extraction [4] was added in a screw cap culture tube. Any solvent present was removed at 55 °C using a nitrogen jet. After cooling down, 3 mL of cyclohexane were accurately added followed by 1 mL of cupric acetate – pyridine reagent and vortex for ~40s. After centrifugation at 2000 rpm for 10 min at 4 °C, the upper layer was read at 710 nm in spectrophotometer (UV-1800 spectrophotometer, Shimadzu, Japan). The FFA concentration in the sample was calculated as µmol oleic acid based on a standard curve spanning a 2-14 µmol range.

Peroxide value (primary oxidation product).

Lipid hydroperoxides (PV) was determined with a modified version of the ferric thiocyanate method [21]. Total lipids were extracted from 5.0 g of samples with 10 mL ice-cold chloroform: methanol (1:1) solution, containing 500 ppm BHT to prevent further peroxidation during the extraction process. Sodium chloride (0.5 M) was added (5.0 mL) into the mixture and homogenized for 30 sec before centrifuging at 5100 rpm for 5 min (TJ-25 Centrifuge, Beckmann Coulter, USA). The chloroform layer was collected (100 µL) and completed with 900 µL chloroform: methanol solution. A total amount of 5 µL of ammonium thiocyanate (4 M) and ferrous chloride (80 mM) mixture (1:1) was finally added. The samples were incubated at room temperature for 10 min and read at 500 nm (Tecan Sunrise, Austria). A standard curve was prepared using cumene hydroperoxides. The results were expressed as mmol lipid hydroperoxides per kg of wet muscle.

Thiobarbituric acid reactive substance (secondary oxidation product).

A modified method of Lemon [14] was used for measuring thiobarbituric acid reactive substance (TBARS). A sample (5.0 g) was homogenized with 10.0 mL of trichloroacetic acid (TCA) extraction solution (7.5% TCA, 0.1% propyl gallate and 0.1% EDTA mixture prepared in ultra-pure water) using a homogenizer at maximum speed for 10 seconds (Ultra-Turrax T-25 basic, IKA, Germany). The homogenized samples were then centrifuged at 5100 rpm for 20 min (TJ-25 Centrifuge, Beckmann Coulter, USA). Supernatant (0.1 mL) was collected and mixed with the 0.9 mL thiobarbituric acid (0.02 M) and heated in a water bath at 95°C for 40 min. The samples were cooled down on ice and immediately loaded into 96-wells microplates (NUNC A/S Thermo Fisher Scientific, Roskilde, Denmark) for reading at 530 nm

(Tecan Sunrise, Austria). A standard curve was prepared using tetraethoxypropane. The results were expressed as µmol of malomaldehyde diethylacetal per kg of wet muscle.

2.6.4 Statistical analysis.

All data summaries and statistical analyses were conducted using STATISTICA software (Version 12.0, StatSoft, Inc. 2300 East 14th Street Tulsa, OK 74104 USA) and MS- Excel 2013 ((Microsoft Inc. Redmond, WA, USA). Means between two methods (liquid smoke and wood smoke) were compared using t-test independent. The Tukey HSD test was used to compare the different means between storage times. Pearson correlation was used to test the relationship between quality attributes (color, texture, free fatty acid, peroxide value, thiobarbituric acid reactive substance and total plate counts) and storage time. Significance of difference was defined at $p<0.05$.

III. RESULTS AND DISCUSSION

3.1 Sensory evaluation

The odour and flavour of fresh mackerel and smoked mackerel after smoking and during chilled storage are shown in Table 3 and Table 4.

Table 3. The odour, flavour and texture of fresh mackerel fillet.

Sensory attribute	Score	Sensory attribute	Score	Sensory attribute	Score
O-oil	36	F-oil	35	T-soft	45
O-metallic	29	F-metallic	36	T-juicy	50
O-sweet	39	F-sweet	37	T-tender	58
O-mouldy	2	F-acidic	15	T-mushy	31
O-butiric	1	F-mouldy	2	T-sticky	29
O-rancid	9	F-bitter	12		
		F-rancid	9		

O: odour; F: flavour; T: texture

Table 4. The odour and flavour changes of liquid and wood smoked mackerel, after smoking and chilled storage.

Group	O-butiric	O-rancid	O- sour	O-TMA	O-spoilage	F-bitter	F-rancid	F- sour	F-TMA	F-spoilage
Day 0										
L	4	7	3	1	1	11	17	1	1	1
W	4	3	5	1	2	13	6	4	0	1
p-value	0.390	0.258	0.350	0.664	0.002 **	0.616	0.024 *	0.111	0.664	0.359
Day 7										
L	3	6	4	1	4	7	14	5	1	1
W	5	2	1	1	0	12	4	3	0	2
p-value	0.058 ms	0.122	0.003 **	0.572	0.026 *	0.037 *	0.004 **	0.042 *	0.418	0.784
Day 14										
L	3	3	3	2	1	11	8	3	4	3
W	6	2	2	1	1	15	3	4	2	3
p-value	0.027 *	0.590	0.101	0.330	0.428	0.036 *	0.000 ***	0.329	0.041 *	0.922
Day 21										
L	13	12	9	3	10	13	16	11	1	4
W	10	6	2	1	2	20	7	10	1	7
p-value	0.218	0.002 **	0.002 **	0.114	0.000 ***	0.081 ms	0.019 *	0.647	0.427	0.411

ms (marginal significance, p = 0.05-0.10); * (p < 0.05); ** (p < 0.01); *** (p < 0.001)

O: odour; F: flavour; L: Liquid smoked group; W: wood smoked group

The p- value in each row indicated a significant difference within each attribute between two smoked groups in the same storage time (p- value <0.05).

The results indicated that after smoking, smoked mackerel fillets were higher in butyric odour and rancid flavour but less rancid odour than fresh mackerel fillets. The liquid smoked product had more rancid flavour but less spoilage odour than the wood smoked

group ($p<0.05$). Other sensory attributes were however rather similar, not different after smoking between the two methods. After one week of chilled storage, significant difference between the liquid and wood groups was observed with regard to rancid odour and sour odour and flavour. These parameters were evaluated to be higher for the liquid smoke group. However, the wood smoke group was evaluated more bitter than the liquid smoke group ($p<0.05$).

The wood smoked sample had more butyric acid odour and bitter flavour, but less rancid and trimethylamine flavour than the liquid smoked sample after two weeks of chilled storage ($p<0.05$). For the other attributes, the difference was not significant at that time. Rancid odour was detected at higher level for the liquid smoke group after three weeks of chilled storage, and this trend was the same for spoilage, sour odour, and rancid flavour ($p<0.05$). After smoking and during chilled storage, trimethylamine odour and other spoilage flavours were evaluated as not significant between the two groups. Data in Week 4 (day 28) was not presented since the microbial results (data was not showed) was not safe for sensory evaluation.

3.2 Color

The lightness of the fillets was measured on a scale from 0 to 100 (from black to white). The results of the final products are shown in Fig 1.

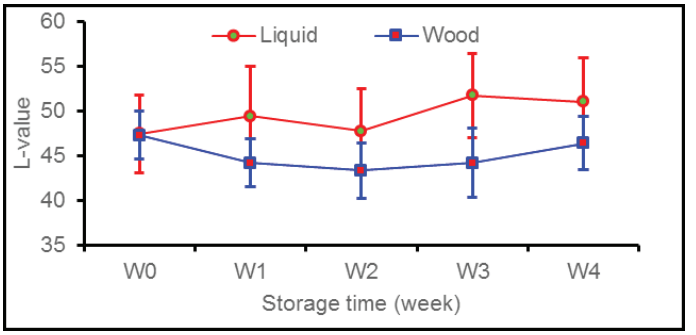

Fig. 1. The lightness (L value) of liquid and wood smoked mackerel fillets after smoking and during chilled storage at -1 °C for 1 week, and then at 4 °C for up to 4 weeks (Mean ± Standard Deviation; n = 3)

After smoking, no significant difference in lightness was observed between the two groups. However, during chilled storage the liquid smoked product was always higher in lightness than the wood smoked product ($p<0.05$).

For the liquid smoked group, a significant positive correlation between change in lightness and storage time ($r= 0.26$, $p=0.007$) was observed. The lightness of the liquid group started to increase from Week 3 of storage time ($p=0.047$). The result also indicated that the wood smoked sample decreased with regard to lightness although the reduction was not significant ($r= -0.07$, $p= 0.45$).

Significant difference in redness was observed between the two groups after smoking, however, this difference was not significant during prolonged chilled storage. The redness of the two sample groups was generally rather stable during the storage time (Fig. 2).

The yellowness of the liquid smoked mackerel was significantly higher compared with the wood smoked mackerel after one week ($p<0.001$) and after three weeks ($p=0.003$) of storage time (Fig.3).

No difference was found between the groups at the last week of the chilled storage. With time, the yellowness increased significantly for both the liquid smoked group ($r= 0.61$, $p<0.001$) and the wood smoke group ($r= 0.70$, $p<0.001$).

According to Bugueno et al. [1] colour of smoked salmon produced through smoked brining was stable for 25 days storage at 2 °C. C. However, in the present study the lightness and yellowness of the liquid smoked mackerel

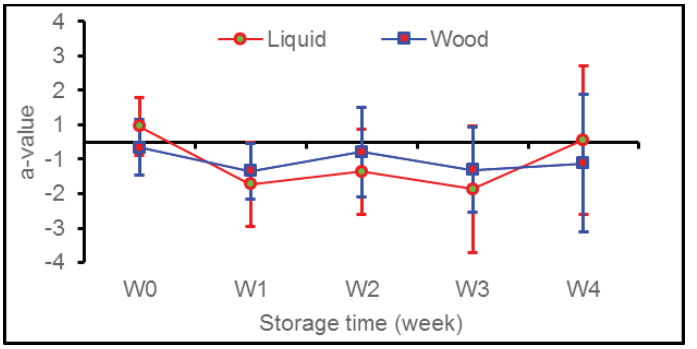

Fig. 2. The redness (a-value) of liquid and wood smoked mackerel fillets after smoking and during chilled storage at -1 °C for 1 week, and then at 4 °C for up to 4 weeks (Mean ± Standard Deviation; n = 3).

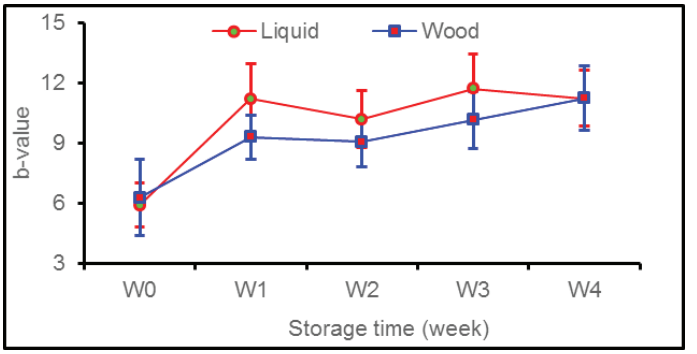

Fig. 3. The yellowness (b-value) of liquid and wood smoked mackerel fillets after smoking and during chilled storage at -1 °C for 1 week, and then at 4 °C for up to 4 weeks (Mean ± Standard Deviation; n = 3).

increased significantly while redness was stable with time. For the wood smoked group, only yellowness correlated positively with time while lightness and redness were stable during the chilled storage.

3.3 Texture

After smoking, the flesh of both treatment groups was firmer compared to the raw material. The shear force was 23.07±5.81 N and 25.86±6.96 N for the liquid smoked sample and the wood smoked sample, respectively, while the shear force of the raw material was 12.84 N. This result was similar with a result observed by Sigurgisladottir *et al*. [22] in smoked Atlantic salmon.

The shear force of the liquid and wood smoked mackerel was the same at Week 0 (after smoking) and Week 1 of storage time (Fig. 4). A marked difference between groups was only found at Week 2, where the shear force

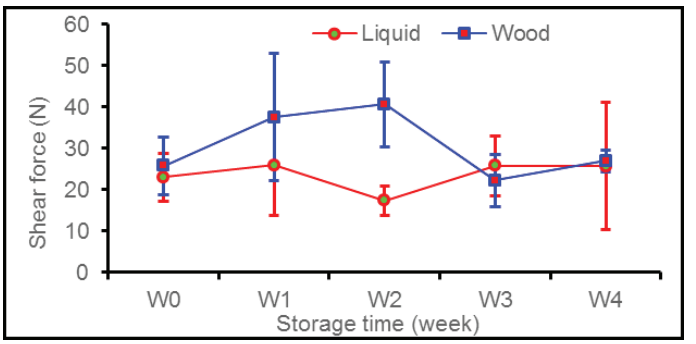

Fig. 4. The shear force (N) of liquid and wood smoked mackerel fillets after smoking and during chilled storage at -1 °C for 1 week, and then at 4 °C for up to 4 weeks (Mean ± Standard Deviation; n = 3).

of the wood smoked (40.69±10.26 N) was significantly higher (p=0.005) than the shear force of the liquid smoked group (17.35±3.46 N). The results also showed that the shear force of the liquid smoked mackerel increased slightly (r=0.08, p=0.73) throughout the chilled storage, while the texture tended to decrease (r = -0.17, p=0.47) in the wood smoked sample although the reduction was not significant.

The liquid smoked mackerel, in present study became stiffer with time which was in accordance with the finding of Siskos *et al.* [24] where with increased storage time, liquid smoked fillets of trout became firmer. Further, the same trend was also seen for liquid smoked salmon [5] where the products became tougher during storage time.

3.4 Lipid quality

Lipid content, free fatty acids content (FFA), PV and TBARS are shown in Fig. 5a, 5b, 5c and 5d, respectively. The lipid content of the liquid and wood smoked samples after smoking and during storage was rather similar (p>0.05).

The lipid content of the liquid smoked mackerel was stable during storage while the lipid content of the wood smoked group, increased (r=0.71, p=0.02). According to Alcicek and Atar [1], the lipid content of the samples was not significantly influenced by different smoking and brining processing conditions during storage. In the present study, lipid content decreased from raw material to smoked product, and a similar result was found on smoked salmon by Espea et al. [9]. However, there was no difference significant in lipid content of liquid and wood smoked mackerel in the present study. This study also confirmed the result from Espea et al. [9] on smoked salmon, where no correlation between lipid content of raw material and TBARS was observed, and oxidation was more progressive at the higher smoking temperature.

The amount of free fatty acids (FFAs) decreased in both groups after smoking although the reduction was not significant. Moreover, there was no significant difference in FFA content between the two groups after

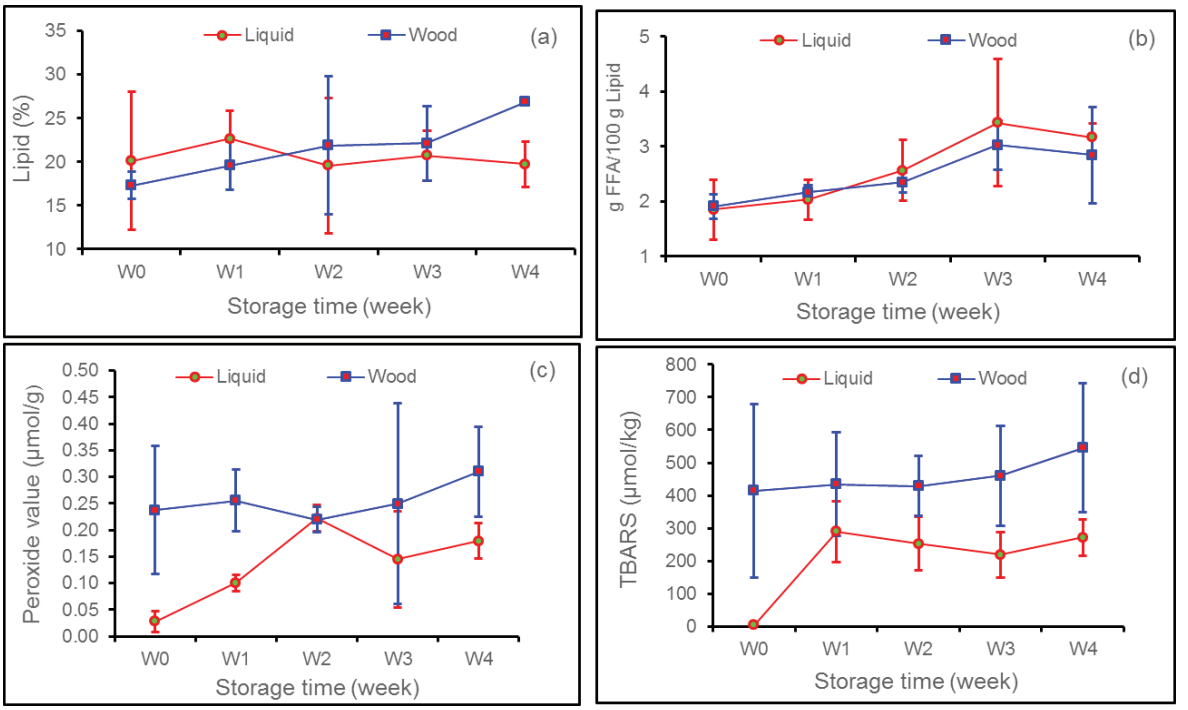

Fig. 5. The lipid content (%) (a), free fatty acids (FFA/g lipid) (b), peroxide value (µmol/g) (c) and TBARS (µmol/kg) (d) of liquid and wood smoked mackerel fillets after smoking and during chilled storage at -1 °C for 1 week, and then at 4 °C for up to 4 weeks (Mean ± Standard Deviation; n = 3).

smoking and during storage time. However, the FFA in the liquid smoked sample increased significantly (r= 0.68, p=0.001) from Week 3 of chilled storage. Positive correlation between increased FFA of wood smoked sample and storage time was also indicated from week three (r= 0.67, p=0.001).

Higher primary and secondary lipid oxidation products (PV and TBARS respectively) were observed in the wood smoked samples compared to the liquid smoked samples (Fig. 5c and 5d). The PV in wood smoked mackerel was higher after smoking (p=0.001), at Week 1 (p<0.001) and at the last week of chilled storage (p=0.005) than the liquid smoked group. A positive correlation between increased PV and storage time was observed for liquid smoked samples (r= 0.62, p< 0.001). The PV value for liquid smoked sample was highest (0.22 µmol/g) at Week 2, but for the wood smoked group, the PV was stable with time.

The TBARS of raw material was 1370.47 µmol/kg. After smoking TBARS decreased strikingly to 4.25 µmol/kg (liquid smoked product) and 414.62 µmol/kg (wood smoked product). The results indicated that the TBARS was lower in the liquid smoked samples, both immediately after smoking and during the storage time, compared to the wood smoked samples (p<0.05). Positive correlation between increased TBARS in liquid smoked mackerel and storage time was indicated (r=0.54, p=0.02), however the wood smoked mackerel was rather stable in TBARS with time.

The lipid oxidation increased with time. These results were in contrast with Siskos *et al.* [24] where they reported that storage at 4 ±1 °C had little effect on lipid oxidation of smoked trout fillet. Antonia da Silva *et al.* [2] reported that smoking increased the TBARS value of smoked blue catfish, and reduced PV significantly in the sample soaked in 5% sorbic acid/30 min. However, in the present study, TBARS decreased surprisingly, and PV increased during the storage time.

In the study of Go´mez-Estaca *et al.* [11] on cold smoked dolphin fish treated with high pressurized, TBARS level was stable during chilled storage and little higher at the end of the storage. In compare with the present study, TBARS increased after one week then was stable at the end of storage. The results from this study are in contrast with Bugueno *et al.* [5] where no changes in TBARS value of smokebrined salmon under vacuum until 25 days of being smokebrined.

IV. CONCLUSION

The results of the present study indicated that, smoked mackerel using commercial liquid smoke flavourings tended to be higher in lightness, redness, and yellowness but softer than wood smoking. These attributes were higher after the wood smoke processing and rather stable during chilled storage. In contrast, liquid smoke processing led less oxidation in the product, but it increased significantly during the storage time.

The options of smoking traditionally or by liquid smoke technique is highly dependent on the material, the point of view of processor and the processing conditions. However, the liquid smoke technique is more convenient through processing and could be better to control the temperature than the traditional smoking house.

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