ACTA VET. BRNO 2012, 81: 397–402; doi:10.2754/avb201281040397

The effect of glaze and storage temperature on the quality of frozen mackerel fillets

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Received May 4, 2012
Accepted August 13, 2012

Abstract

The effect of glazing and storage temperature on lipid oxidation and sensory properties of mackerel fillets was evaluated. A total of 288 fillets were stored for 6 months under stable temperature of –18 °C and unstable temperature, which involved six temperature fluctuation cycles from –18 to –5 °C each month. Glaze determination, chemical composition, thiobarbituric acid reactive substances examination and sensory evaluation of fillets were performed. Glazing and stable temperature conditions slowed down lipid oxidation in fillets compared to unglazed samples and samples stored under unstable freezing conditions. The thiobarbituric acid reactive substances increased slowly in glazed samples and a positive effect of stable conditions was found after two months and became obvious from the fifth month of storage. Sensory scores included evaluation of taste, aroma, texture, juiciness, and appearance corresponded to chemical results. Glazed fillets had the best scores in sensory evaluation and can be recommended for consumption; on the other hand, unglazed fillets stored under unstable temperature could not be consumed because of rancidity. This is the first similar study in mackerel when unstable temperature conditions are considered as a factor increasing lipid oxidation. Prevention of temperature fluctuation during storage is important to keep the quality of the frozen fillets.

Lipid oxidation, sensory properties, thiobarbituric acid reactive substances

Although freezing is an effective method of preserving foods, some deterioration in frozen food quality occurs during storage. The extent of quality loss depends on many factors, including the rate of freezing and thawing, storage temperature, temperature fluctuation, transportation, retail display and consumption (Boonsumrej et al. 2007). In this circumstance, factors such as mild temperature abuse or storing foods at very low temperatures may have varying effects on the quality, depending on the product.

In fatty species of fish such as herring (*Clupeidae*), anchovy (*Engraulidae*), mackerel (*Scombridae*), and salmon (*Salmonidae*), the most serious cause of deterioration is oxidation. Fish lipids contain high levels of polyunsaturated fatty acids, which are susceptible to attack by molecular oxygen, when lipid oxidation typically results in formation of aldehydes, alkyl radicals and semialdehydes (Chen et al. 2008). The chemical tests for detecting oxidation and quantifying the extent of oxidation are based upon these changes. Thus, malondialdehyde (MDA), a major degradation product of lipid oxidation is used as a marker for assessing the extent of lipid oxidation and the most frequently method used for MDA determination is estimation of thiobarbituric acid reactive substances (TBARS) (Cordis et al. 1995). However, TBARS values go up during the initial phase of propagation stage and down in the termination stage of oxidation, the lipid oxidation leads also to objectionable changes of flavours, therefore sensory tests provided useful information related to quality loss (Mendes et al. 2009).

The aim of this study was to estimate the effect of glazing on lipid oxidation and sensory indicators in mackerel fillets during freezing storage under stable and unstable temperatures.

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Materials and Methods

Raw material

A total of 288 fillets of the Atlantic mackerel (*Scomber scombrus*) from catching area FAO 27 (Ireland) were used to assess the effect of glazing on oxidative changes in lipids and sensory properties during six-month storage under frozen conditions. Fillets were frozen immediately after catching and the time from catching to processing under laboratory conditions was approximately two weeks. The fillets were divided into four groups based on glazing (glazed and unglazed) and temperature regimes (stable and unstable): control unglazed fillets (CS) and glazed fillets (GS) stored under stable freezing conditions, control unglazed fillets (CU) and glazed fillets (GU) stored under unstable freezing conditions with fluctuation of temperature. Twelve fillets were examined in each group every month and glaze determination, chemical composition, thiobarbituric acid reactive substances examination and sensory evaluation were performed.

Process of glazing and storage conditions

Mackerel fillets were frozen at a temperature below –35 °C until the fish cores had reached –18 °C. Two groups (GS and GU) were glazed by dipping in container continuously supplied with fresh cold potable water (1 °C). Two groups (CS and GS) were packed into polyethylene bags and immediately stored under constant freezing conditions (–18 °C) for six months. Temperature fluctuation of other two groups (CU and GU) involved a total of six temperature fluctuation cycles performed at the end of each month. Subsequently, the samples of fish from these groups were thawed in cold conditions (0–2 °C) until fish cores had reached –5 °C and after re-freezing stored at constant temperature of –18 °C again. Samples were analysed immediately and after 1, 2, 3, 4, 5 and 6 months of frozen storage. Prior to analysis, frozen fillets were kept at +4 °C until they reached a core temperature of –1 °C.

Glaze determination

Glaze was determined according to the Codex Standard (1995) method. As soon as the package was removed from low temperature storage, the content was placed under a gentle spray of cold water. The fillets were agitated carefully to avoid damage and sprayed until ice glazes that could be seen or felt were removed. Adhering water was removed by paper towel and fillets were weighed. Six independent determinations were carried out for each group.

Chemical composition analysis

Moisture was determined according to the official methods of analysis (AOAC 1995) using oven-drying method. Crude protein was calculated as N × 6.25 (AOAC 1995). Soxhlet method (ISO 1444:1996) was used to estimate free fat content in fillets. Six samples were taken in the first month of storage and analyses were carried out in duplicate.

Determination of thiobarbituric acid reactive substance (TBARS)

Determination of TBARS was performed according to the method described by Marcincak et al. (2004). Malondialdehyde (MDA) was extracted from sample with 1 ml 0.3% aqueous ethylene diamine tetraacetic acid disodium salt (EDTA). After gentle agitation, 5 ml 0.8% butylated hydroxytoluene (BHT) in hexane, and before homogenization (30 s at maximum speed), 8 ml ice-cold 5% trichloroacetic acid (TCA) were added. After centrifugation (5 min at 3500 × *g,* 4 °C), the bottom layer was filtered and diluted with 5% TCA. TBARS was determined after addition of 2 ml of 0.8% TBA into test tube with 3 ml of sample. Samples and standard solutions of MDA were incubated in water bath at 70 °C for 30 min. Absorbance of samples was measured on UVspectrophotometer Heλios γ v 4.6 (Thermospectronic, Great Britain) at wavelength 532 nm, and expressed as g of MDA per 1 kg of sample. Stock solution of MDA was prepared by acid hydrolysis tetramethoxypropane and used for preparation of calibration curve (0.17–0.7 $\mu g \cdot ml^{-1}$).

Sensory evaluation

A scoring test, paired comparison test (ISO 5495:2005), was used for the determination of the sensory quality of the frozen fillets. The samples were thermally treated using two methods: keeping in hot steam until they achieved internal temperature of 65 °C and frying in the oven at 180 °C for 20 min. After cooking, fillets were served to the six panellists to evaluate the sensory attributes. Five point intensity scale for each of the following properties (maximum score 25 points): taste, aroma, texture, juiciness, and appearance were applied.

Statistical analysis

Group means and standard deviations were calculated using column statistics, followed by one-way ANOVA analysis of variance, Tukey's multiple comparison test (GraphPad Prism 5, 2007); and treatments were considered significantly different at $P < 0.05$.

Results

The amounts of glaze in the groups stored under stable and unstable temperature conditions are shown in Table 1. Differences in the proportion of glaze between CS (2.5%) and CU (4.6%) groups were found to be significant ($P < 0.05$) from the first month of storage and these changes further increased until the sixth month of storage (4.9% and

6.8% for CS and CU, respectively). Differences in the amount of glaze between the group GS (9.9%) and GU (11.6%) became significant ($P < 0.05$) after three months of storage and these changes remained constant until the end of storage.

In the CS group, during six months of storage, the highest amount of glaze (4.9%) was measured in the sixth month and was significantly ($P < 0.05$) higher compared to all previous months. The portion of glaze in CU group, from second month achieved the value of 5.1%, which must be (when exceeding 5%) indicated on the packaging and labelled in the product name as well as in its composition. In the GS group there was no significant ($P > 0.05$) increase in the proportion of glaze throughout the six months storage. Significant differences ($P < 0.05$) in the proportion of glaze (11.6%) in the GU group were evident after three months of storage and were consistently higher in all other months of storage.

Table 1. Amount of glaze (%) in mackerel fillets (mean ± SD)

Sample	Month of storage						
	0	1.	2.	3.	4.	5.	6
CS	$1.11^{a1} \pm 0.01$	$2.53^{a2} \pm 0.12$	$2.11^{a1} \pm 0.08$	$3.45^{a2} \pm 0.31$	$3.28^{a2} \pm 0.46$	$3.65^{a23} \pm 0.38$	$4.86^{a3} \pm 0.61$
GS	$9.04^{b} \pm 0.04$	$9.02^{c} \pm 0.23$	$9.24^{bc} \pm 0.28$	$9.93^{b} \pm 0.43$	$9.27^{b} \pm 0.36$	$9.46^{b} \pm 0.58$	$9.38^{b} \pm 0.45$
CU	$1.11^{a1} \pm 0.01$	$4.59^{b2} \pm 0.38$	$5.15^{b23} \pm 0.50$	$6.01^{b3} \pm 0.49$	$6.47^{b3} \pm 0.31$	$6.32^{b3} \pm 0.26$	$6.82^{b4} \pm 0.39$
GU	$9.04^{b1} \pm 0.04$	$9.20^{c1} \pm 0.31$	$9.53^{c1} \pm 0.33$	$11.62^{c2} \pm 0.83$	$11.41^{c2} \pm 0.48$	$11.54^{c2} \pm 0.63$	$11.65^{c2} \pm 0.59$

^{a,b,c} within rows, different superscript letters indicate significant differences ($P < 0.05$)
^{1,2,3} within columns, different superscript numbers indicate significant differences ($P < 0.05$)
CS - control unglazed fillets stored under stable freezing conditions, GS - glazed fillets stored under stable freezing conditions, CU - control unglazed fillets stored under unstable freezing conditions, GU - glazed fillets stored under unstable freezing conditions

Table 2 shows the chemical composition of fillets. No differences ($P > 0.05$) in moisture, protein and fat content were found for fillets stored under stable and unstable freezing conditions. Slight differences in water (60.1–60.3%), protein (16.5–16.8%) and fat content (21.6%–22.5%) were found among the groups.

Table 2. Chemical composition of mackerel fillets in % (mean ± SD)

Sample	Moisture	Protein	Fat
CS	60.16 ± 3.917	16.50 ± 0.549	21.59 ± 4.434
GS	60.15 ± 4.181	16.63 ± 0.670	22.50 ± 4.789
CU	60.27 ± 1.552	16.68 ± 0.689	21.83 ± 2.133
GU	60.08 ± 1.840	16.78 ± 1.084	22.26 ± 2.684

CS - control unglazed fillets stored under stable freezing conditions, GS - glazed fillets stored under stable freezing conditions, CU - control unglazed fillets stored under unstable freezing conditions, GU - glazed fillets stored under unstable freezing conditions

The impact of glaze (GS and GU) and stable temperature conditions (–18 °C) in CS group on the extent of changes in fat oxidation compared to unglazed samples stored under unstable conditions (CU) was found to be positive ($P < 0.05$) after two months of storage (Table 3). The protective effect of stable storage conditions was obvious from the fifth month of storage when the MDA content in CS and GS was lower compared to samples stored under unstable conditions (CU and GU) when even glazing in GU group did not prevent arising of oxidation changes ($P < 0.05$).

Table 3. Fat oxidation (expressed as an amount of malondialdehyde mg·kg^{-1}) in mackerel fillets (mean ± SD)

Sample	Month of storage						
	0	1	2	3	4	5	6
CS	$7.28^{a1} \pm 0.59$	$7.45^{a1} \pm 0.48$	$10.88^{a2} \pm 1.43$	$11.16^{a2} \pm 0.41$	$12.86^{b2} \pm 1.27$	$13.01^{a2} \pm 0.73$	$13.75^{a2} \pm 0.63$
GS	$6.59^{a1} \pm 0.038$	$7.44^{a1} \pm 0.83$	$9.05^{a2} \pm 0.26$	$9.78^{a2} \pm 0.51$	$10.98^{a3} \pm 0.56$	$11.35^{a3} \pm 1.04$	$11.79^{a3} \pm 0.80$
CU	$7.28^{a1} \pm 0.59$	$8.58^{a1} \pm 0.63$	$13.52^{b2} \pm 1.32$	$14.53^{b2} \pm 0.72$	$18.56^{c3} \pm 1.64$	$18.03^{b3} \pm 1.21$	$19.25^{b3} \pm 1.10$
GU	$6.59^{a1} \pm 0.04$	$8.14^{a1} \pm 0.33$	$11.58^{a2} \pm 0.69$	$12.22^{a2} \pm 1.14$	$13.94^{b3} \pm 0.74$	$14.73^{b3} \pm 1.02$	$15.68^{b3} \pm 1.11$

[a,b,c] within rows, different superscript letters indicate significant differences ($P < 0.05$)
[1,2,3] within columns, different superscript numbers indicate significant differences ($P < 0.05$)
CS - control unglazed fillets stored under stable freezing conditions, GS - glazed fillets stored under stable freezing conditions, CU - control unglazed fillets stored under unstable freezing conditions, GU - glazed fillets stored under unstable freezing conditions

The results of sensory evaluation of fillets after six months of storage are given in Table 4. Glazed fillets stored at stable freezing conditions were generally more desirable than control groups. Significant differences were found using the frying method when glazed samples were rated higher compared to CU (unglazed stored under unstable conditions) ($P < 0.05$). Sensory analysis showed that at the end of frozen storage samples from CU group had the worst score in evaluation of taste and odour and could not be consumed because of rancidity.

Table 4. Sensory evaluation of mackerel fillets at the end of frozen storage using five point descriptive methods (mean ± SD)

Sample	Boiling method	Frying method
CS	21.50 ± 1.05	21.67 ± 1.75^{ab}
GS	21.33 ± 2.34	22.50 ± 0.55^{a}
CU	19.83 ± 1.47	19.67 ± 1.51^{b}
GU	20.33 ± 1.63	22.17 ± 1.17^{a}

Within rows, different superscript letters indicate significant differences ($P < 0.05$)
CS - control unglazed fillets stored under stable freezing conditions, GS - glazed fillets stored under stable freezing conditions, CU - control unglazed fillets stored under unstable freezing conditions, GU - glazed fillets stored under unstable freezing conditions

Discussion

Ice-glazing is applied to protect the frozen fishery products from undesirable quality changes during frozen storage. The predominant quality changes are caused by oxidation, denaturation of proteins and recrystallization of ice crystals. These can result in off-flavours, rancidity, dehydration, weight loss, loss of juiciness, drip loss and toughening, as well as microbial spoilage (Jacobsen and Fossan 2001). Layer of ice prevents access of air to the product surface and thus reduces the degree of oxidation. Glaze is usually applied at a rate of 4 to 10% depending on the product, although the range varies from 2 to 20%. In extreme cases, on some marine products, observed rate was from 25 to 40% of glaze. Adequate glazing (6–10%) of fish fillets prior to frozen storage protects the final product from dehydration, oxidation and quality loss. Excessive glazing (> 12%) on the other hand may significantly affect the economic value and end user satisfaction of frozen fish fillets (Vanhaecke et al. 2010).

Fish belonging to the family *Scombridae* are considered as fat fish with the fat content ranging from 10 to 20%. Mackerel and sardine contain important amounts of lipids (7.1 and 5.7 g/100 g). The differences, if they exist, may be explained by the large variability of the oil level in the fish flesh, which depends on the species, period of the year, age, size, gender, reproduction period, fishing zone or breeding method, the specific species, food and even particularly large individual variability (Sirot et al. 2008).

Because of the high content of polyunsaturated fatty acids, fish are highly

susceptible to lipid oxidation during handling, processing and heat treatment. As a result of oxidative changes hydroperoxides are formed and these so-called products of secondary oxidation may alter the quality of food, including color, texture, smell and taste. One of the main oxidation products MDA is considered as a carcinogenic initiator and mutagen; however, MDA is often used as a marker of oxidative damage in biological samples and food (St. Angelo 1996). It has been proposed that a maximum TBA value (indicating the good quality of the fish frozen, chilled or stored with ice) is 5 mg MDA/kg, while the fish may be consumed up to a level of 8 mg MDA/kg in TBA value (Schormüller 1969).

Frozen fillets of the Alaska pollack were used to evaluate the effect of glaze on lipid oxidation and sensory properties during 6 months of storage. Despite the low fat content in the Alaska pollack, a positive effect of glazing and stable freezing conditions of storage on the range of oxidative changes of lipids was found. According to the microbiological results fillets stored under unstable conditions were considered to be acceptable, but sensory evaluation showed that at the end of frozen storage they could not be consumed because of rancidity (Žoldoš et al. 2011). Freezing without glaze is preferable for storage of prawns for less than 2 months. However, for long-term storage, it must be emphasized that glazing is essential to preserve acceptable bacteriological, chemical and organoleptic quality parameter values. Deteriorative changes are the result of several *post-mortem* biochemical alterations and may be perceived by changes in sensorial analysis (Mendes et al. 2005).

In conclusion, quality of frozen fish and fish products is deteriorated during storage if they are not adequately protected against effects of dehydration and oxidation, and also physical damage and environmental contamination. The keeping of rules and conditions of glazing of fish can be profitable also in case of unstable conditions of storage and transportation. In contrast, when the rules are not kept, partial thawing of fish and repeated freezing can have a negative impact on the acceptance of products.

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