Bulgarian Chemical Communications, Volume 51, Special Issue A (pp. 216-223) 2019

Enhancement of sensory acceptance of frozen mackerel by alga-extract glazing

M. Trigo[1], M. López[1], G. Dovale[2], J. Ortiz[2], A. Rodríguez[2], S. P. Aubourg[1,*]

[1] *Department of Food Technology, Marine Research Institute (CSIC), c/ E. Cabello, 6, Vigo (Spain)*
[2] *Department of Food Science and Chemical Technology, Faculty of Chemical and Pharmaceutical Sciences, University of Chile, Santiago (Chile)*

Submitted February 22, 2019; Revised March 14, 2019

This research focusses on the rancidity stability of mackerel species during frozen storage. Its basic objective was to investigate the effect of including an ethanolic and aqueous extract of algae *Bifurcaria bifurcata* and *Fucus spiralis* in the glazing system previously to the frozen storage. For it, two independent experiments were carried out, i.e., employment of a *B. bifurcata*-glazing system on Atlantic Chub mackerel (*Scomber colias*) and a *F. spiralis*-glazing system on Atlantic mackerel (*Scomber scombrus*). In both cases, quality changes were monitored for a 8-month frozen storage by raw (eyes, external odour, gills and flesh odour) and cooked (flesh odour and taste) sensory descriptors; complementary chemical analyses related to lipid oxidation were also carried out. As a result, both experiments showed a sensory acceptance increase in frozen fish by including algae extracts in the glazing media. This effect showed to be significant ($p < 0.05$) for descriptors such as eyes, external odour and cooked flesh odour (*B. bifurcata* experiment), and for external odour, gills and raw flesh odour (*F. spiralis* experiment). In most cases, an increasing effect could be observed by increasing the content of the alga extract in the glazing system. A novel alga-extract based glazing system is proposed to be applied for the quality enhancement of fatty fish species during their commercialisation under frozen conditions. Such tool can be considered a profitable and practical strategy in agreement with the availability and commercial cost of the materials employed. Further research would be necessary to optimise the experimental conditions.

Keywords: Mackerel species; *Bifurcaria bifurcata*; *Fucus spiralis*; glazing; sensory acceptance; shelf-life.

INTRODUCTION

Fish has long been recognised as a valuable source of high-quality digestible proteins, long-chain ω3 fatty acids, fat-soluble vitamins (A and D), as well as essential minerals and vitamins [1]. However, during the frozen storage of fatty fish, lipid hydrolysis and oxidation have been shown to occur and become an important factor of fish acceptance as influencing the development of off-odours and off-flavours [2, 3]. Consequently, different strategies have been tested to extend the shelf-life time during the frozen storage of such kind of seafood.

One traditional technology greatly used is the application of an ice layer to the surface of the frozen seafood, referred as glazing [4, 5]. Thus, adequate glazing of marine specimens prior to frozen storage can protect the final product from oxidation, dehydration and general quality loss. Interestingly, previous research has shown profitable effects of glazing when combined to other preservative strategies by inhibiting lipid hydrolysis [6, 7] and oxidation [8, 9] development.

To extend the shelf-life time during the frozen storage of marine species, the employment of natural preservatives also represent a relevant choice. Recently, red, green and brown macroalgae have offered the possibility of exploring a wide variety of natural compounds with potential antioxidant activity [10, 11]. In this sense, a wide number of preservative metabolites such as polyphenols, terpenes, phlorotannins, steroids, halogenated ketones and alkanes, fucoxanthin, polyphloroglucinol or bromophenols have been isolated from macroalgae [12, 13]. Among brown macroalgae, extracts obtained from *Bifurcaria bifurcata* [14, 15] and *Fucus spiralis* [16, 17] have recently attracted a great attention because of their preservative behaviour in refrigerated and canned seafood.

The present research was focussed on the rancidity stability of mackerel species during the frozen storage. Its basic objective was to investigate the effect of including an ethanolic and aqueous extract of *B. bifurcata* and *F. spiralis* in the glazing system previously to the frozen storage. For it, two independent experiments were carried out, i.e., employment of a *B. bifurcata*-glazing system on Atlantic Chub mackerel (*Scomber colias*) and a *F. spiralis*-glazing system on Atlantic mackerel (*Scomber scombrus*). In both cases, quality changes were monitored for a 8-month frozen storage by sensory (raw and cooked descriptors) analysis. Complementary chemical analyses related to lipid oxidation were also carried out.

* To whom all correspondence should be sent:
E-mail: saubourg@iim.csic.es

MATERIALS AND METHODS

Preparation of algae extracts and glazing systems

The lyophilised algae *B. bifurcata* and *F. spiralis* were provided by Porto-Muiños (Cerceda, A Coruña, Spain).

Two glazing systems were prepared including *B. bifurcata* extracts. For it, 7 and 21 g lyophilised *B. Bifurcata* were mixed, respectively, with absolute ethanol (2 x 120 mL), stirred for 30 s and centrifuged at 3,500 rpm for 10 min at 4 ºC. Then, the supernatants were recovered and filled to 250 mL with absolute ethanol. Additionally, the remaining lyophilised alga samples were mixed with distilled water (2 x 120 mL), stirred for 30 s and centrifuged at 3,500 rpm for 10 min at 4 ºC. Then, the supernatants were recovered, pooled together with the corresponding previously obtained ethanolic extracts and the mixture was diluted to 11 L with distilled water (0.64 and 1.92 g lyophilised alga·L^{-1} aqueous solution, respectively). As a result, low-concentrated (B-3 condition) and high-concentrated (B-4 condition) glazing systems were obtained. Finally, a glazing control was also prepared. For it, 250 mL of absolute ethanol were diluted to a 11-L solution with distilled water and employed as water glazing control (B-2 condition).

The same procedure (starting alga quantity and extracting volumes) was carried out for preparing the *F. spiralis* extracts and the corresponding glazing systems. As a result, low-concentrated (F-3 condition) and high-concentrated (F-4 condition) glazing systems were obtained that were accompanied by a water glazing control (F-2 condition).

Fish material, processing and sampling

Two separated and independent experiments were carried out. In the first one, the effect of a glazing system including *B. bifurcata* extracts on frozen Atlantic Chub mackerel was analysed. In the second, Atlantic mackerel was treated with a glazing system including *F. spiralis* extracts, their effects being then analysed during frozen storage.

Thus, fresh Atlantic Chub mackerel (102 specimens) were caught near the Galician Atlantic coast (North-Western Spain) and transported to the laboratory. Throughout this process (10 h), the fish were maintained in ice. The length and weight of the fish specimens ranged from 24.5 to 28.0 cm and from 107 to 123 g, respectively. Upon arrival to the laboratory, six specimens were separated and analysed as initial fish. These fish specimens were divided into three different groups (two individuals per group) that were analysed independently to achieve the statistical analysis; $n = 3$). The remaining fish specimens were divided into four batches (24 individuals in each batch) that were immediately frozen at –40 ºC.

After 48 hours at –40 ºC, the first batch was packaged in polyethylene bags (two pieces per bag) and stored at –18 ºC (blank control; non-glazed batch; B-1 batch). At the same time, the remaining batches were immersed, respectively, in the above-mentioned B-2, B-3 and B-4 glazing systems. In all cases, specimens were immersed for 30 s at 0 ºC, allowed to drain for 15 s, packaged in polyethylene bags (two pieces per bag) and stored at –18 ºC. Sampling was undertaken at months 2, 4, 6 and 8 of frozen storage at –18 ºC. At each time and for each condition, six individuals were taken, that were divided into three groups (two individuals per group) and studied separately. Analysis of frozen material was undertaken after thawing; thawing was carried out by overnight storage in a cool room (4 ºC).

Concerning the second experiment (i.e., effect of *F. spiralis*-glazing on frozen Atlantic mackerel), fresh fish (102 specimens) were caught near the Galician Atlantic coast (North-Western Spain) and transported to the laboratory. Throughout this process (10 h), the fish were maintained in ice. The length and weight of the fish specimens ranged from 25.5 to 29.5 cm and from 109 to 127 g, respectively.

The same processing procedure (freezing, glazing and frozen storage) as in the previous experiment was carried out. As a result, four different batches were obtained (F-1, blank control, non-glazed batch; F-2, water glazing control; F-3, low-concentrated alga glazing; F-4, high-concentrated alga glazing). Furthermore, the same sampling procedure (sampling times, number of individuals per sample and thawing conditions) was carried out.

Determination of sensory acceptance

Sensory analysis was carried out by a sensory panel consisting of four to six experienced judges. Before carrying out the present experiment, the judges received special training on frozen mackerel species. Special attention was paid to the evolution of the sensory descriptors that were found as limiting factors for the shelf-life. Consequently, descriptors analysed were: eyes, external odour, gills, raw flesh odour, cooked flesh odour and cooked flesh taste. The different descriptors were evaluated on a scale from 7.0 (stage of highest quality) to 0.0 (stage of lowest quality) in agreement with Lehmann and Aubourg [18]. Four rang categories were considered [19]: 7.0-5.6 (excellent), 5.5-3.6 (good), 3.5-1.6 (fair) and 1.5-0.0 (rejectable).

At each sampling time, fish individuals from each batch were analysed. Evaluation began by the analysis of fish in the raw state and was followed by the analysis of samples in the cooked state. Cooking was accomplished at 95-100 ºC for 7 min in a pre-warmed oven with air circulation and then submitted to the panel. At each sampling time, whole fish specimens were coded with 3-digit random numbers and presented to the panellists in individual trays, which were scored individually. Each descriptor of each sample was scored a single time by each member of the panel. The panel members shared samples tested. Global evaluation was calculated for each sample taking into account the six individual descriptors.

Chemical assessment of lipid oxidation

Lipids were extracted from the fish white muscle by the Bligh and Dyer [20] method, based on a single-phase solubilisation of the lipids with a chloroform-methanol (1:1) mixture.

Peroxide value (PV) was determined spectrophotometrically on the lipid extract by peroxide reduction with ferric thiocyanate, according to Chapman and McKay [21]. The results were calculated as meq. active oxygen·kg^{-1} lipids.

Thiobarbituric acid index (TBA-i) was determined according to Vyncke [22]. This method is based on the reaction between a trichloracetic acid extract of the fish muscle and thiobarbituric acid. Content of thiobarbituric acid reactive substances (TBARS) was spectrophotometrically measured at 532 nm and calculated from a standard curve using 1,1,3,3-tetraethoxy-propane (TEP). Results were calculated as mg malondialdehyde·kg^{-1} muscle.

Statistical analysis

Data obtained from the different sensory descriptors and global evaluation were subjected to the ANOVA method to explore differences resulting from the effect of the glazing system. The comparison of means was performed using the least-squares difference (LSD) method. In all cases, analyses were carried out using the PASW Statistics 18 software for Windows (SPSS Inc., Chicago, IL, USA); differences among batches were considered significant for a confidence interval at the 95% level ($p < 0.05$) in all cases.

RESULTS AND DISCUSSION

Frozen Atlantic Chub mackerel experiment

Evaluation of the sensory acceptance provided a progressive quality loss with time in all kinds of frozen samples (Tables 1-2). Concerning raw descriptors (Table 1), B-2 batch showed not to be acceptable at the end of the study (external odour assessment), while all others were still acceptable at that time. Higher average scores were obtained in most cases for treated fish (i.e., B-3 and B-4 batches) when compared to both controls (B-1 and B-2 batches). Such differences were found significant ($p < 0.05$) when evaluating eyes (6-8-month period) and external odour (month 8). Interestingly, higher average values were obtained in most cases for fish corresponding to B-4 condition when compared to their counterpart from B-3 batch, so that a partial effect of alga extract concentration could be implied. Scarce significant differences ($p < 0.05$) (i.e., external odour at month 8) could be observed between both controls, so that a definite effect of water glazing could not be concluded.

Concerning cooked descriptors (Table 2), scores obtained indicated a quality loss throughout storage, this leading to non-acceptable values at the end of the experiment for both controls when analysing the taste; consequently, this descriptor could also be considered as limiting factor in the current experiment. Comparison among samples led to scarce significant differences; thus, an inhibitory effect of *B. bifurcata* extract presence in the glazing medium could only be inferred at month 2 (flesh odour assessment) for samples corresponding to the most concentrated condition (batch B-4). Interestingly, treated fish (B-3 and B-4 glazing conditions) showed in most cases higher average values than their counterpart controls.

In agreement with the individual analysis of raw and cooked descriptors, the global sensory evaluation (Fig. 1) showed higher average values for treated fish when compared to both controls. However, significant differences could not be observed ($p > 0.05$). In most cases, higher average values were obtained in fish corresponding to the B-4 batch when compared to their counterparts from B-3 condition; consequently, a partial increasing effect could be inferred for the concentration of the alga extract present in the glazing medium.

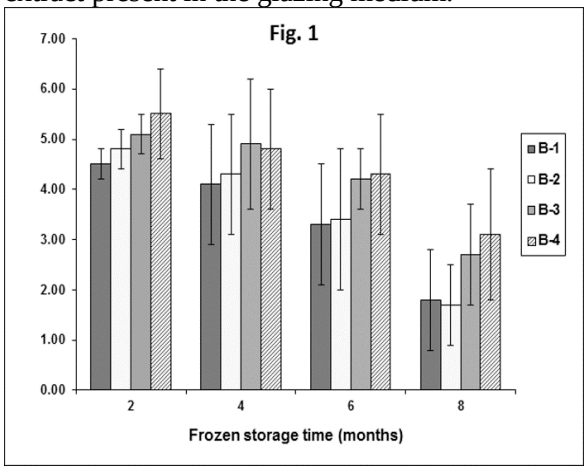

Figure 1: Evolution* of global sensory acceptance of frozen Atlantic Chub mackerel previously submitted to different glazing conditions**

* Average values of three replicates (n = 3); standard deviations are indicated by bars.
** Glazing conditions as expressed in Table 1.

Determination of chemical parameters related to lipid oxidation development did not provide a definite effect of *B. bifurcata* extracts in the glazing system. Thus, a general low peroxide formation (< 10.0) was observed in the 0-6-month period; interestingly, a marked increase (21.8 value) was detected at month 8 in fish corresponding to the B-1 batch, while all other samples were found below a 12.0 score. For secondary lipid oxidation, the TBA-i showed low values (< 0.8) in all kinds of samples for the 0-6-month period. At the end of the experiment, a 2.07 value was observed for B-1 samples, lower levels (< 1.2) being found in all other batches. As a result, no differences ($p > 0.05$) were inferred between fish from the water-glazing control and their counterparts from B-3 and B-4 conditions..

Table 1. Sensory acceptance (raw descriptors)* of frozen Atlantic Chub mackerel previously submitted to different glazing conditions**

Descriptor/frozen time (months)	Glazing condition			
	B-1	**B-2**	**B-3**	**B-4**
Eyes				
2	4.5 (0.7)	4.5 (0.7)	5.5 (0.7)	5.5 (0.7)
4	3.5 (2.1)	3.0 (1.4)	4.3 (1.5)	4.7 (1.5)
6	3.3 a (0.6)	3.3 a (0.6)	4.0 b (0.0)	4.0 b (0.0)
8	1.7 a (0.6)	1.7 a (0.6)	3.3 b (0.6)	3.3 b (0.6)
External odour				
2	4.5 a (0.7)	4.5 a (0.7)	5.0 a (0.0)	6.0 b (0.0)
4	4.7 ab (1.2)	4.0 a (1.0)	5.3 ab (1.2)	5.7 b (0.6)
6	4.0 (1.7)	3.3 (1.2)	5.0 (1.0)	4.7 (1.2)
8	2.0 b (0.0)	1.0 a (0.0)	3.3 c (0.6)	3.7 c (1.5)
Gills				
2	5.0 (0.0)	5.0 (0.0)	5.5 (0.7)	5.0 (1.4)
4	5.3 (0.6)	4.7 (0.6)	4.7 (0.6)	5.3 (0.6)
6	4.0 (0.0)	4.0 (0.0)	4.0 (0.0)	4.0 (0.0)
8	1.7 (0.6)	1.7 (0.6)	2.3 (0.6)	2.3 (0.6)
Flesh odour				
2	4.0 (0.0)	4.5 (0.7)	4.5 (0.7)	5.0 (1.4)
4	3.7 (0.6)	4.7 (1.5)	5.0 (1.0)	4.3 (1.5)
6	2.7 (1.5)	3.3 (2.3)	4.0 (1.0)	4.0 (2.0)
8	2.7 (2.1)	2.3 (1.5)	2.7 (1.2)	3.3 (1.5)

* Descriptors were evaluated on a scale from 7.0 (highest stage of quality) to 0.0 (lowest stage of quality) in agreement with the Material and Methods section. Values followed by different letters (a, b, c) indicate significant differences ($p < 0.05$). No letters are included when significant differences were not found ($p > 0.05$). Initial fish was assigned score 7.0 in all descriptors.
** Abbreviations of conditions: B-1 (blank control), B-2 (glazing control), B-3 (low-concentrated alga condition) and B-4 (high-concentrated alga condition), in agreement with the Material and Methods section.

Table 2. Sensory acceptance (cooked descriptors)* of frozen Atlantic Chub mackerel previously submitted to different glazing conditions**

Descriptor/frozen time (months)	Glazing condition			
	B-1	**B-2**	**B-3**	**B-4**
Flesh odour				
2	4.0 a (0.0)	5.0 b (0.0)	5.0 b (0.0)	6.0 c (0.0)
4	3.7 (0.6)	4.5 (0.7)	5.0 (1.0)	4.7 (1.2)
6	3.0 (1.0)	3.3 (2.3)	3.7 (0.6)	4.3 (1.5)
8	1.7 a (0.6)	2.3 ab (1.5)	2.7 ab (1.2)	3.7 b (1.2)
Taste				
2	5.0 (0.0)	5.0 (0.0)	5.0 (0.0)	5.5 (0.7)
4	4.0 (1.0)	5.0 (1.0)	5.0 (1.0)	4.3 (0.6)
6	3.0 (1.0)	3.3 (0.6)	4.3 (0.6)	4.7 (1.2)
8	1.3 (0.6)	1.0 (0.0)	1.7 (0.6)	2.0 (1.0)

* Descriptors were evaluated on a scale from 7.0 (highest stage of quality) to 0.0 (lowest stage of quality) in agreement with the Material and Methods section. Values followed by different letters (a, b, c) indicate significant differences ($p < 0.05$). No letters are included when significant differences were not found ($p > 0.05$). Initial fish was assigned score 7.0 in all descriptors.

** Abbreviations of glazing conditions as expressed in Table 1.

Frozen Atlantic mackerel experiment

Sensory acceptance was also analysed by means of raw and cooked descriptors (Tables 3-4). A progressive quality loss was evident in all samples with storage time for both kinds of descriptors. However, all kinds of samples were found acceptable at the end of the experiment. Comparison among batches showed higher average values in treated fish in most cases. A significant inhibitory effect ($p < 0.05$) of the alga presence in the glazing medium could be observed in external odour (month 8 for both treated batches), gills (month 8 for both treated batches) and raw flesh odour (month 8, only for F-3 fish). Consequently, an inhibitory effect on sensory quality loss could be inferred by the presence of the alga extract in the glazing system at both concentrations. Comparison between both batches including alga extract provided scarce differences, so that a definite trend of the alga content presence on the sensory acceptance could not be proved in this experiment. Furthermore, no significant differences ($p > 0.05$) were observed between both control batches (namely, F-1 and F-2).

The global sensory evaluation (Fig. 2) led to higher average values in frozen fish including *F. spiralis* extract in the glazing system than in their counterpart controls; however, as in the previous experiment, differences were not found significant ($p > 0.05$). As for individual descriptors, the global evaluation led to very scarce differences between both batches including the alga extract in the glazing system (i.e., F-3 and F-4), so that a definite trend could not be inferred concerning the alga extract content in the glazing system.

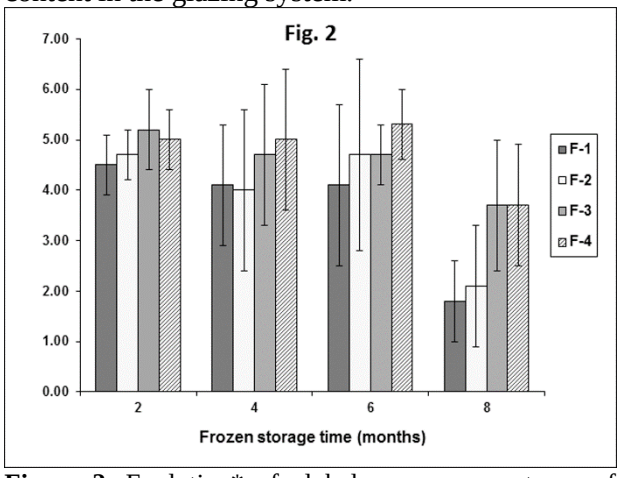

Figure 2: Evolution* of global sensory acceptance of frozen Atlantic mackerel previously submitted to different glazing conditions**

* Average values of three replicates ($n = 3$); standard deviation.

** Glazing conditions as expressed in Table 3.

Chemical assessment of primary and secondary lipid oxidation development did not lead to a definite

effect of *F. spiralis* extracts in the glazing system. Throughout the whole experiment, PV were found lower than 2.0 score in all cases; however, fish corresponding to the B-1 batch was included in the 1.2-1.9 range, while all other samples revealed values lower than 1.3. Concerning the TBA-i determination, low scores (< 0.4) were obtained for all kinds of samples in the 0-4-month period. Then, a general increase was observed, higher average values being obtained for F-1 fish. It is concluded that the assessment of chemical lipid parameters did not show differences ($p > 0.05$) between fish belonging to water-glazing conditions and their counterparts including the *F. spiralis* extracts.

Table 3. Sensory acceptance (raw descriptors)* of frozen Atlantic mackerel previously submitted to different glazing conditions**

Descriptor/frozen time (months)	Glazing condition			
	F-1	F-2	F-3	F-4
Eyes				
2	4.3 (0.6)	4.7 (0.6)	5.0 (1.0)	5.0 (1.0)
4	3.5 (0.7)	3.5 (0.7)	4.0 (0.0)	5.0 (1.4)
6	5.0 (0.0)	5.0 (0.0)	4.5 (0.7)	5.0 (0.0)
8	2.3 (1.5)	2.3 (1.5)	4.3 (1.2)	4.7 (1.5)
External odour				
2	4.0 (0.0)	4.7 (0.6)	5.0 (1.0)	5.0 (1.0)
4	4.0 a (0.0)	4.7 ab (1.5)	4.7 ab (0.6)	5.5 b (0.7)
6	4.5 (0.7)	5.5 (0.7)	4.5 (0.7)	5.0 (0.0)
8	2.0 a (0.0)	1.7 a (0.6)	3.3 b (0.6)	3.3 b (0.6)
Gills				
2	4.7 (0.6)	4.7 (0.6)	5.0 (1.0)	5.0 (1.0)
4	4.3 (0.6)	4.3 (1.5)	4.3 (1.2)	4.3 (1.2)
6	4.5 (0.7)	5.5 (0.7)	4.5 (0.7)	5.0 (0.0)
8	2.0 a (0.0)	1.7 a (0.6)	3.3 b (0.6)	3.3 b (0.6)
Flesh odour				
2	4.7 ab (0.6)	4.3 a (0.6)	5.7 b (0.6)	5.3 ab (0.6)
4	4.3 (1.5)	4.0 (1.0)	5.0 (1.0)	5.0 (1.7)
6	4.0 (2.8)	4.5 (2.1)	5.0 (0.0)	5.5 (0.7)
8	1.7 a (0.6)	2.0 ab (1.0)	4.7 c (1.2)	3.7 bc (1.2)

* Descriptors were evaluated on a scale from 7.0 (highest stage of quality) to 0.0 (lowest stage of quality) in agreement with the Material and Methods section. Values followed by different letters (a, b, c) indicate significant differences ($p < 0.05$). No letters are included when significant differences were not found ($p > 0.05$). Initial fish was assigned score 7.0 in all descriptors.

** Abbreviations of conditions: F-1 (blank control), F-2 (glazing control), F-3 (low-concentrated alga condition) and F-4 (high-concentrated alga condition), in agreement with the Material and Methods section.

Table 4. Sensory acceptance (cooked descriptors)* of frozen Atlantic mackerel previously submitted to different glazing conditions**

Descriptor/frozen time (months)	Glazing condition			
	F-1	F-2	F-3	F-4
Flesh odour				
2	4.7 (0.6)	5.0 (0.0)	5.3 (0.6)	5.0 (0.0)
4	4.3 (1.5)	3.5 (2.1)	5.0 (1.7)	5.0 (1.0)
6	3.5 (2.1)	4.5 (2.1)	4.5 (0.7)	5.5 (0.7)
8	1.7 a (0.6)	2.3 ab (0.6)	4.0 ab (1.7)	3.7 b (1.2)
Taste				
2	4.7 (0.6)	5.0 (0.0)	5.3 (0.6)	5.0 (0.0)
4	4.3 (1.5)	4.0 (1.0)	5.0 (1.7)	5.3 (1.2)
6	3.0 (1.4)	4.0 (2.8)	4.5 (0.7)	5.0 (1.4)
8	1.7 a (0.6)	2.0 ab (1.0)	3.3 b (0.6)	3.3 b (0.6)

* Descriptors were evaluated on a scale from 7.0 (highest stage of quality) to 0.0 (lowest stage of quality) in agreement with the Material and Methods section. Values followed by different letters (a, b) indicate significant differences ($p < 0.05$). No letters are included when significant differences were not found ($p > 0.05$). Initial fish was assigned score 7.0 in all descriptors.

** Abbreviations of glazing conditions as expressed in Table 3.

DISCUSSION

The presence in fish species of a highly unsaturated lipid composition and a great content of pro-oxidant molecules have been reported as the most decisive factors influencing the shelf-life of frozen fatty fish products [2, 3]. As damage mechanisms responsible for this quality loss, enzymatic and non-enzymatic rancidity development has been pointed at as responsible for the development of off-odours and off-flavours. In agreement with the results of the current study, a sensory quality enhancement of frozen seafood has been obtained as a result of previous glazing including both algae extracts [12, 13].

As photosynthetic organisms, algae are known to be exposed to a combination of light and high oxygen concentration. The lack of structural damage in their organs has led to consider that their protection against oxidation would arise from their natural content on antioxidant substances. Concerning *B. bifurcata* extracts, previous research has shown the presence of antioxidant compounds, an antioxidant behaviour (DPPH, reducing activity, and beta-carotene *in-vitro* assays) [23-25] and a quality enhancement effect in chilled [14] and canned [15] seafood. Thus, various kinds of compounds related to a preservative behaviour have been isolated and identified such as phenols [26], diterpenes [27], sterols [28] and polysaccharides [29]. On the other hand, a wide number of studies have shown the antioxidant possibilities of *F. spiralis* extracts by means of *in-vitro* studies (DPPH and FRAP tests) [13, 30], the presence of antioxidant structures such as polyphenols [31] and α-tocopherol [32], as well as the presence of pholorotannins was proved by quadrupole time-of-flight mass spectrometry [33]; additionally, its preservative effect on the quality retention of refrigerated seafood was demonstrated [16, 17]. Interestingly, the current study represents the first attempt of employing extracts of both algae for the quality enhancement of frozen fish as glazing systems; markedly, sensory analysis was found more advantageous than chemical analysis to assess the effect of algae extracts presence.

Previous research accounts for the employment of natural preservative compounds from non-algae sources as a way of enhancing the shelf-life time in frozen seafood. Thus, the employment of a glazing system including rainbow sardine (*Dussumieria acuta*) protein hydrolysates led to a longer shelf-life time (higher scores in colour, odour, taste, firmness and general appearance) of frozen (6 months at –18 ºC) black pomfret (*Parastromateus niger*) fillets [34]. Also related to the present study, average score

values of rancid odour development were found slightly higher for frozen (–18/–20 ºC for 52 weeks) herring (*Clupea harengus*) control fillets than for their counterpart fillets previously submitted to glazing treatment including the herring muscle press juice [9]. Furthermore, the employment of a glazing system including a by-product resulting from squid (*Dosidicus gigas*) processing (i.e., skin) led to a lipid hydrolysis inhibition and to a sensory acceptance increase in Atlantic Chub mackerel [7]. Finally, a quality enhancement (lipid hydrolysis and oxidation inhibition and sensory acceptance increase) was inferred in frozen Atlantic mackerel by the presence of a saponin-free quinoa extract in the glazing system [6].

CONCLUSION

A glazing system based on the inclusion of ethanolic and aqueous extracts of *B. bifurcata* and *F. spiralis* has been tested for the sensory quality enhancement of frozen Atlantic Chub mackerel and Atlantic mackerel, respectively. The analysis of the raw and cooked descriptors revealed a sensory quality enhancement in fish submitted to glazing conditions including both algae extracts.

Under the conditions tested in the present study, a novel alga-extract based glazing system is proposed to be applied for the quality enhancement of fatty fish species during their commercialisation under frozen conditions. Such tool can be considered a profitable and practical strategy in agreement with the availability and commercial cost of the materials employed. Further research would be necessary to optimise the experimental conditions (i.e., extract concentration) when applied to different kinds of fatty seafood.

Acknowledgements. *This work was supported by the Project PIE 2013-70E001 (CSIC, Spain).*

REFERENCES

1. A. Tacon, M. Metian, *Rev. Fish. Sci*., **21**, 22 (2013).
2. M. Richards, H. Hultin, *J. Agric. Food Chem*., **50**, 555 (2002).
3. A. Kolakowska, in: Chemical and functional properties of food lipids, Z. Sikorski, A. Kolakowska (eds), CRC Press, London, UK, 2003, p. 133.
4. L. Vanhaecke, W. Verbeke, H. De Brabander, *Anal. Chim. Acta*, **672**, 40 (2010).
5. P. Yerlikaya, N. Gokoglu, *Int. J. Food Sci. Technol*., **45**, 252 (2010).
6. M. Trigo, A. Rodríguez, G. Dovale, A. Pastén, A. Vega-Gálvez, S. P. Aubourg**,** *LWT-Food Sci. Technol.*, **98**, 231 (2018).
7. J. M. Ezquerra-Brauer, M. Trigo, W. Torres-Arreola, S. P. Aubourg, *Bulg. Chem. Comm*., **50 Special Issue**, 131 (2018).
8. S. Sundararajan, A. Prudente, D. Bankston, J. King, P. Wilson, S. Sathivel, *J. Food Sci*., **76**, E511 (2011).
9. L. Cavonius, I. Undeland, *Int. J. Food Sci. Technol*., **52**, 1229 (2017).
10. T. Wang, R. Jónsdóttir, H. Kristinsson, G. Thorkelsson, C. Jacobsen, P. Yuca Hamaguchi, G. Olafsdóttir, *Food Chem*., **123**, 321 (2010).
11. S. Halldorsdóttir, H. Sveinsdóttir, A. Gudmundsdóttir, G. Thorkelsson, H. Kristinsson, *J. Funct. Foods*, **9**, 10 (2014).
12. J. Fleurence, M. Morançais, J. Dumay, P. Decottignies, V. Turpin, M. Munier, N. García-Bueno, P. Jaouen, *Trends Food Sci. Technol*., **27**, 57 (2012).
13. I. Peinado, J. Girón, G. Koutsidis, J. M. Ames, *Food Res. Int*., **66**, 36 (2014).
14. J. M. Miranda, J. Ortiz, J. Barros-Velázquez, S. P. Aubourg, *Food Bioproc. Technol.*, **9**, 387 (2016).
15. R. G. Barbosa, M. Trigo, R. Fett, S. P. Aubourg, *J. Sci. Food Agric.*, **98**, 3462 (2018).
16. B. García-Soto, J. M. Miranda, A. Rodríguez-Bernaldo de Quirós, R. Sendón, A. Rodríguez-Martínez, J. Barros-Velázquez, S. P. Aubourg, *Int. J. Food Sci. Technol*., **50**, 1891 (2015).
17. J. M. Miranda, M. Carrera, J. Barros-Velázquez, S. P. Aubourg, *Food Cont.* **90**, 407 (2018).
18. I. Lehmann, S. P. Aubourg, *Int. J. Food Sci. Technol*., **43**, 270 (2008).
19. European Council Regulation, European Community (EC), No 2406/96, 26 November 1996. *Off. J. Eur. Comm.*, L-334/2:23.12 (1996).
20. E. Bligh, W. Dyer, *Can. J. Biochem. Physiol.*, **37**, 911 (1959).
21. R. Chapman, J. McKay, *J. Am. Oil Chem. Soc*., **26**, 360 (1949).
22. W. Vyncke, *Fette Seifen Anstrichm*., **72**, 1084 (1970).
23. S. Connan, E. Deslandes, E. Gall, *J. Exp. Mar. Biol. Ecol*., **349**, 359 (2007).
24. K. Le Lann, C. Jégou, V. Stiger-Pouvreau, *Phycol. Res*., **56**, 238 (2008).
25. M. Zubia, M. S. Fabre, V. Kerjean, K. Le Lann, V. Stiger-Pouvreau, M. Fauchon, E. Deslandes, *Food Chem.*, **116**, 693 (2009).
26. K. Glombitza, H. Rösener, M. Koch, *Phytochem.*, **15**, 1279 (1976).
27. G. Culioli, M. Daoudi, A. Ortalo-Magne, R. Valls, L. Piovetti, *Phytochem*., **57**, 529 (2001).
28. N. Bouzidi, Y. Daghbouche, M. El Hattab, Z. Aliche, G. Culioli, L. Piovetti, S. Garrigues, M. De la Guardia, *Anal. Chim. Acta*, **616**, 185 (2008).
29. E. Gómez-Ordóñez, P. Rupérez, *Food Hydroc*., **25**, 1514 (2011).
30. P. Andrade, M. Barbosa, R. Pedro Matos, G. Lopes, J. Vinholes, T. Mouga, P. Valentão, *Food Chem*., **138**, 1819 (2013).
31. M. Tierney, T. Smyth, M. Hayes, A. Soler-Vila, A. Croft, N. Brunton, *Int. J. Food Sci. Technol*., **48**, 860 (2013).
32. L. Paiva, E. Lima, R. Ferreira Patarra, A. Neto, J. Baptista, *Food Chem*., **164**, 128 (2014).
33. M. Tierney, T. Smyth, D. Rai, A. Soler-Vila, A. Croft, N. Brunton, *Food Chem*., **139**, 753 (2013).
34. A. Taheri, *J. Aquat. Food Prod. Technol*., **24**, 241 (2015).