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Effect of chitosan-based solutions applied as edible coatings and water glazing on frozen salmon preservation – A pilot-scale study

Nuno M. Soares, Tânia S. Mendes, António A. Vicente *

IBB – Institute for Biotechnology and Bioengineering, Centre of Biological Engineering, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal

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ABSTRACT

The aim of this research was to compare the effect of chitosan solutions on frozen salmon preservation with that of water glazing. For this purpose, three chitosan solutions (0.25%, 0.50% and 0.75% w/v) and water were applied in different amounts (6%, 8% and 11% of coated fillet weight) directly on the surface of frozen salmon. In order to accelerate the deterioration processes, salmon was stored during 14 weeks at −5 °C. Microbial and chemical indices were used to assess deterioration during storage and the coating stability was evaluated through weight loss measurements. The results obtained showed that chitosan coatings can be a good barrier to protect frozen fish from deterioration. Microbial growth, assessed by total viable counts (TVC), and total volatile basic nitrogen (TVB-N) were maintained below the maximum limits recommended which are 5×105 CFU/g and 35 mg nitrogen/100 g fish, respectively. The use of 0.50% and 0.75% chitosan solutions generally demonstrated to be more efficient in preventing salmon weight loss.

1. Introduction

The search for healthier products is an increasingly important drive to consumers' food choices. Fish is much known for its richness in several nutrients as protein, vitamins D and E, selenium and long-chain polyunsaturated fatty acids, such as omega-3. Thus fish is perceived as an important part of a healthy diet among nutrition and food scientists as well as consumers (Brunsø et al., 2008; Doré, 2008). In the last decades, the consumption of this food group increased and became available to consumers far away from the coastal areas. However, fresh fish is among the most perishable foodstuffs due to various intrinsic factors, such as high water-holding capacity, neutral pH values, tissue enzymes, low connective tissue content and natural microbial contamination (Kilincceker et al., 2009). Thus, the improvement of food preservation techniques in order to carry fish safely to the consumers and retain its organoleptic characteristics is a major concern of seafood industry.

Freezing is a common option among the methods existing for long term preservation of fish. This process inhibits microbial growth and slows down the enzymatic activity as well as preserves taste and nutritional value (Gonçalves and Gindri Junior, 2009; Jiang and Lee, 2004). Despite freezing preservation efficiency, some undesirable changes such as lipid oxidation, surface dehydration and protein denaturation might occur during frozen storage, negatively affecting the nutritional and sensory quality of frozen fish, thus influencing the acceptability of the product. In seafood industry, glazing is a technology widely used to protect the processed frozen fish during storage. This process consists in creating a water coating on the surface of frozen product by spraying or dipping the product in water. This coating reduces the rate of oxidation by excluding air from the product surface. In addition, it retards the freezer burn since the glaze will sublime instead of the tissue water. The amount of glaze depends on the product size and shape, the water and product temperature and the glazing time (Johnston et al., 1994). Typically, the glaze content ranges from 8% to 12% of the gross weight, though larger amounts are sometimes used (Jacobsen and Fossan, 2001). The determination and control of glaze content is very important in seafood industry, since small quantities of glaze might not protect the product efficiently and excessive amounts may cause economic loss for consumers.

Nevertheless, temperature fluctuations often occur during handling and transport of frozen fish which cause losses in the glaze, reducing its protective effect. Thus, it is of great importance to develop coatings that combine the mentioned positive features of glaze with a longer protection.

According to Rodriguez-Turienzo et al. (2011), lipid oxidation and/or moisture losses during frozen storage of fish can be reduced by applying edible coatings on the surface of the product since they act as a barrier against moisture and oxygen transfer, helping to maintain the quality of frozen food and extending shelf life. Depending on the desired characteristics, various materials might be used, singly or in combination, to prepare edible coatings. As

* Corresponding author. Tel.: +351 253604419; fax: +351 253678986.
E-mail address: avicente@deb.uminho.pt (A.A. Vicente).

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a general rule, proteins are utilized to provide mechanical stability, polysaccharides are applied to control oxygen and other gases transmission and fats are used to reduce water transfer (Pavlath and Orts, 2009). Foods with a high level of unsaturated fats which are easily oxidized, such as Atlantic salmon, would be best protected by a polysaccharide barrier. Chitosan-based coatings have been tested by several authors in an attempt to maintain quality and prolong shelf life of fish products (Rodriguez-Turienzo et al., 2011; Sathivel et al., 2007; Souza et al., 2010). This non-toxic, biodegradable, biofunctional and biocompatible polysaccharide has been reported to present antimicrobial and antifungal activity while also being able to incorporate substances such as vitamins and minerals (Dutta et al., 2009; Leroi et al., 2008).

Usually, assessing frozen fish freshness is a time consuming activity because it requires analysis during long periods. In order to accelerate this evaluation, several authors have developed models to predict quality deterioration and shelf life of a variety of products during frozen storage (Gonçalves et al., 2011; Martins et al., 2005). Tsironi et al. (2009) have investigated and modeled the effect of variable storage temperatures (−5, −8, −12 and −15 °C) on shelf life and quality characteristics of frozen shrimp and demonstrated the applicability of the models in the cold chain. According to their results, storage temperature highly influences deterioration processes with higher temperatures leading to shorter shelf life.

The aim of this work was to compare the protective effect of different chitosan-based coatings, applied directly on frozen salmon, with that of a water coating. In order to understand the contribution of coating content to the overall protective effect, different amounts of coating were also tested. To accelerate the deterioration processes, treated salmon was stored during 14 weeks at −5 °C. Fish processing and sample preparation were performed at pilot-scale in an industrial environment.

2. Materials and methods

2.1. Fish samples

Frozen and vacuum packaged Atlantic salmon (*Salmo salar*) fillets were kindly provided by *Lerøy Seafood Group* (Bergen, Norway). After unpacking, an industrial vertical bone sawing machine was used to cut the salmon fillets in loins with the dimensions 10 cm × 5 cm × 2–3 cm and an average weight of 79.1 ± 5.2 g. This process was carried out in a refrigerated room to minimize temperature uptake and the salmon samples were stored at −18 °C until further use.

2.2. Coating solutions

Coating solutions with different chitosan (Golden-shell Biochemical Co. Ltd. (China) with 91% degree of deacetylation) concentrations (0.25%, 0.50% and 0.75% w/v) were prepared by adding the corresponding mass in a 1% v/v lactic acid and stirring at room temperature until completely dissolved. Water was also used as coating – water glazing.

2.3. Coating application and storage

The frozen fish pieces (−18 °C) were weighted, dipped in chitosan coating solutions (5 °C) or in water (0 °C), for different dipping times, drained for 2 min and weighted again. This coating process was carried out in a pilot-scale glazing tank; samples were collected from the tank with a stainless steel mesh, in order to minimize the interference with the amount of coating applied. Coating uptake was calculated according to Eq. (1), where W_{salmon} and W_i represent the weight of the salmon portion before and after the coating application, respectively. Samples groups with an average coating uptake of 6.1 ± 0.6, 8.1 ± 0.7 and 10.5 ± 0.9 (all values in wt%) were obtained. Salmon pieces belonging to the control group were left untreated.

$$\text{Coating uptake } (\%) = \frac{W_i - W_{salmon}}{W_i} \times 100 \quad (1)$$

All samples were individually packed in polyethylene freezer bags and stored at −5.0 ± 0.6 °C for 14 weeks. This temperature was monitored and registered every 20 min by using a data logger (DS1923 temperature/humidity logger iButton®, Dallas Semiconductors, USA).

During storage, samples were taken in triplicate and separately analyzed to assess fish quality.

2.4. Coating loss

After the storage period, samples were weighted (W_f) and the coating loss was determined by the following equation;

$$\text{Coating loss } (\%) = \frac{W_f - W_i}{(W_i - W_{salmon})} \times 100 \quad (2)$$

2.5. Weight loss

The control salmon pieces were left untreated without addition of any coating. In this case, weight loss was calculated by following the next equation where $W_{salmon,i}$ and $W_{salmon,f}$ represent the weight of the salmon pieces before and after the storage period, respectively.

$$\text{Weight loss } (\%) = \frac{W_{salmon,f} - W_{salmon,i}}{W_{salmon,f}} \times 100 \quad (3)$$

2.6. Microbial analysis

Total viable counts (TVC) were estimated according to the procedure described in the standard ISO 4833 (2003).

2.7. Chemical analysis

2.7.1. Determination of pH

A 5 g portion of each sample was homogenized with 50 mL of ultrapure water in a mixer/blender for 30 s and the pH value of the mixture was measured using a digital pH meter (HI 8711E, HANNA Instruments, Italy).

2.7.2. Determination of 2-thiobarbituric acid (TBA)

The 2-thiobartbituric acid (TBA) value was evaluated colorimetrically using the method of Pokorny and Dieffenbacher (1989). Briefly, a 500 mg portion of each sample was weighed and added to 25 mL of 1-butanol. Using a pipette, 5 mL of the sample solution and 5 mL of TBA reagent were transferred to a dry test tube. The test tube was stoppered, thoroughly mixed using a vortex, and placed in a thermostated water bath at 95 °C for 120 min. After cooling in running tap water, the optical density was measured at 530 nm in a 10 mm quartz cell, using distilled water in the reference cell, in a Jasco V-560 UV/Vis spectrophotometer (Japan). A reagent blank was run at the same time.

2.7.3. Determination of total volatile basic nitrogen (TVB-N)

The total volatile basic nitrogen (TVB-N) value was determined according to the procedure described in the standard NP 2930 (2009).