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Food Chemistry 97 (2006) 244–247
Food Chemistry
www.elsevier.com/locate/foodchem

Effects of brine concentration on shelf-life of hot-smoked tilapia (*Oreochromis niloticus*) stored at 4 °C

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Received 6 December 2004; accepted 23 March 2005

Abstract

This work evaluated the effect of brine concentration on the shelf-life of hot-smoked tilapia (*Oreochromis niloticus*) stored at 4 °C. The fish were brined in solutions of 5%, 10%, and 15% NaCl and unsalted fish were used as controls. The fish were then smoked, cooled and stored at 4 °C. Oxidative rancidity measured by the peroxide value (PV), and thiobarbituric acid number (TBA) showed increases with the storage time and also as a result of the increasing salt content in fish muscle. Hot smoked tilapia can be stored safely under refrigerated conditions for over 35 days, and 5% brine was found to be optimal for storage.

Keywords: *Oreochromis niloticus*; Smoking; Brining concentration

1. Introduction

Smoking is probably the oldest known method used for preserving fish. At present, the effects of brining and smoking on colour and sensory perception are at least as important as the preservative effect due to the use of modern refrigerating systems. There are three different stages of the total smoking process; brining, heating and smoking (Aminullah Bhuiyan, Ratnayake, & Ackman, 1986). Several studies have been reported on the effect of different smoking processes on fish quality (Cuppet, Gray, Booren, Price, & Stachiw, 1989; Espe, Nortvedt, Lie, & Hafsteinsson, 2002; Jittinandana, Kenney, Slider, & Kiser, 2002;). Jittinandana et al. (2002) found that brine concentration and brining time affected the texture development of smoked rainbow trout. Cuppet et al. (1989) reported that no correlation was found between the levels of salt and the extent of lipid oxidation in smoked whitefish, but they also reported that more research is needed to clarify the effect of salt on the rate of lipid oxidation in food systems.

The preservative effect of salt has been recognised as being due to a decrease in water activity, less availability to microbial attack, and enhancement of functional properties, leading to an increase of the shelf-life time. Although salt allows prolonged storage, its contact with fish has been reported to enhance lipid oxidation of the highly unsaturated lipids, directly related to the production of off-flavours and odours, protein denaturation, and texture changes (Harris & Tall, 1994). Augbourg and Ugliano (2002) reported that increasing the salt content in fish muscle accelerates the rate of oxidative rancidity in salted horse mackerel during frozen storage. There is little information about the effects of salt concentration on the shelf-life of smoked fish and the objectives of this study were to investigate the effect of different salt concentrations on the shelf-life of smoked tilapia (*Oreochromis niloticus*) during refrigerated storage.

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doi:10.1016/j.foodchem.2005.03.043

2. Materials and methods

2.1. Raw material

Tilapia (*O. niloticus*) used for this study were obtained from Cukurova University, Fisheries Faculty, Fresh Water Aquaculture Experimental Units, in November 2002. The fish were harvested, beheaded, gutted manually, and then washed. The weight of the tilapia was in the range 180–200 g.

2.2. Brining and smoking process

The fish were brined in solutions of 5%, 10%, and 15% NaCl and unsalted fish were used as controls. The fish were submerged in brine and kept at 5 °C for 1 h, with the fish to brine ratio at 1:2. The unsalted fish were at 5 °C after being washed.

Smoke was produced from oak sawdust. The processing time in the kiln was divided into two stages: (1) a preliminary drying and cooking period (30 min) at 100 °C; (2) a smoking and partial cooking period at 80 °C (45 min). After cooking and cooling, samples were held at refrigerator temperatures (4 °C) until needed for analysis.

Eight fish from the unsalted and salted lots were randomly selected prior to smoking for proximate composition and salt content analyses. Beginning on the first day after smoking, day 0, and at regular intervals until day 42, samples (three fish per analytical period of each group) were removed from refrigerated storage and analysed for their thiobarbuturic acid number (TBA), total volatile basic nitrogen (TVB-N), peroxide value (PV) and sensory analyses.

2.3. Analysis

Proximate composition: Two-gram samples were used for moisture determination based on AOAC (1980) Method 7.003. Results are expressed as g water/100 g muscle. Ash was determined by the AOAC (1980) Method 7.009. Lipid was extracted from the mixed fish samples with a mixture of chloroform, methanol and water (Bligh & Dyer, 1959). Percent protein (Kjeldahl N × 6.25) was determined from a 1 g sample for each treatment by AOAC (1980) Method 2.507.

NaCl content in fish muscle was determined by the volumetric method of Volhard (AOAC, 1990). The salt content was calculated as percentage of the sample. TBA number was determined using the method of Tarladgis, Watts, Younathan, and Dugan (1960). TBA number was expressed as mg malondialdehyde/kg sample. PV expressed as milimol O_2/kg lipid was determined by the ferric thiocyanate method (AOAS, 1994).

TVB-N was determined on steam distillation using the Kjeldahl distillation apparatus and titration (Botta, Lauder, & Jewer, 1984). Sensory analysis were performed using the methods of Amerina, Pangborn, and Roessler (1965). Smoked fish were assessed on the basis of appearance, odour, taste and texture characteristics using a nine point descriptive scale. A score of 7–9 indicated "very good" quality, a score of 4.0–6.9 "good" quality, a score of 1.0–3.9 denoted as spoiled. Sensory evaluation as conducted using five experienced panellists. The significant effects of brine concentrations on the shelf-life of hot smoked tilapia, as measured by the chemical and sensory evaluations, were determined by the ANOVA method using the SPSS program at $p \leqslant 0.05$.

3. Results and discussion

Table 1 shows the moisture, protein, lipid and ash contents of raw and smoked tilapia. In the corresponding smoked tilapia lot (unsalted smoked), the percentage of total protein, lipid and ash increased due to water loss during smoking. Similar findings were reported by Gomez-Guillen, Montero, Hurtado, and Borderias (2000) in Atlantic salmon and Aminullah Bhuiyan et al. (1986) in Atlantic mackerel.

The proximate composition data for raw fish of Table 1 agrees well with data presented for moisture, protein, lipid and ash by Puwastien et al. (1999).

Results of the effect of salt level on lipid stability indicated that the fish brined in the 5%, 10%, 15% brines and unsalted fish contained 2.09%, 4.17%, 6.26% and 0.95% salt in the water-phase portion of the finished product, respectively. The stability of lipids in smoked tilapia was evaluated by PV and TBA number procedures.

There was a significant difference ($p < 0.05$) in peroxide values between samples brined in 5%, 10% and 15% salt concentrations and unsalted fish during storage. As it can be seen from Fig. 1, there was a general increase with the storage time for all groups. Comparison of the different salt concentrations showed, in most cases, higher peroxide values for fish samples having been immersed in 15% NaCl solutions than those three other groups ($p < 0.05$); a very high value (5.14 mmol O/kg lipid) was obtained at day 42 for 15% NaCl-treated samples ($p < 0.05$). A level of 5 mmol O_2/kg lipid has been

Table 1
Proximate composition (w/w%)[a] of raw and smoked tilapia

Sample component	Raw tilapia	Smoked tilapia unsalted
Water	76.87 ± 0.03	67.96 ± 0.03
Lipid	2.64 ± 0.04 (12.02)	3.14 ± 0.02 (10.69)
Ash	1.09 ± 0.02 (4.96)	2.29 ± 0.03 (7.80)
Protein	18.23 ± 0.03 (83.0)	23.93 ± 0.08 (81.51)
Salt	0.26 ± 0.00	0.95 ± 0.01

[a] Values in parentheses represent percentage on dry basis.

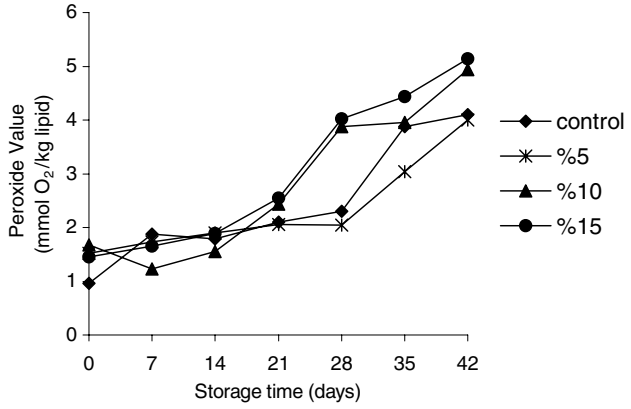

Fig. 1. PV of smoked tilapia brined in different salt concentrations.

considered the upper limit above which fishery products are considered unfit for human consumption (Sikorski, Kolakowska, & Burt, 1990). Augbourg and Ugliano (2002) pointed out that increasing salt concentration in brine accelerates the rate of peroxide value in salted horse mackerel during frozen storage.

Secondary lipid oxidation measured by the TBA number provided a general and gradual increase with the storage time for all groups. Fig. 2 represents the TBA numbers. A strong effect of the presence of salt can be concluded since the 15% NaCl-treated group showed in most cases higher TBA values than the other three groups ($p < 0.05$). At the end of the experiment, a very high TBA value (2.90 mg malondialdehyde/kg sample) was obtained from samples that had been treated with 15% NaCl ($p < 0.05$). A number of studies have demonstrated that salt stimulates lipid oxidation via iron activation. Sodium ions may displace iron from macromolecules such as myoglobin, providing free iron ions for the catalysis of lipid oxidation (Kanner, Harel, & Jaffe, 1991; Liu, Booren, & Gray, 1997). The results of this study showed that lipid oxidation rate in the smoked tilapia during refrigerated storage depended on salt concentration. While high values of PV and TBA numbers were found in the samples treated with 15% NaCl, low levels were observed with the samples treated with 5% NaCl solutions. This results indicates that salt concentrations of 5% prevented lipid oxidation during storage. Rust and Olson (1973) stated that to function as the sole preservative, a minimum salt concentration is necessary. Current curing practices employ salt in the form of sodium chloride at levels of 2–3% (Price & Schweigert, 1987).

Fig. 3 shows TVB-N results. The TVB-N contents increased from initial values of 5.86–6.32 mg TVB-N/100 g to 38.89, 36.80, 34.80 and 39.15 mg TVB-N/100 g at 5%, 10%, 15% NaCl concentrations and in unsalted fish respectively, throughout the period of storage. A level of 30 mg/100 g has been considered the upper limit above which fishery products are considered unfit for human consumption (Sikorski et al., 1990). As can be seen in Fig. 3, increased salt concentration had a positive effect on extending the shelf-life of the products when TVB-N production was a criterion for quality. Ishida, Fujii, and Kadota (1976) found TVB-N values did not exceed 30 mg per 100 g with their study on salted mackerel at 15% NaCl but exceed it at 5% concentration. A similar result was observed in this study.

Fig. 4 shows the results of the sensory analysis. The overall acceptability scores decreased with an increase in storage time for all groups. Sensory scores changed during the storage depending on the different salt concentrations. The scores of samples were found to be below 4 at the 35th day for unsalted fish, at 42nd day for 5%, 10% and 15% salt concentrations. The samples had "very good" quality up to 21 days for 5%, 10% and 15% salt concentrations, 14 days for unsalted fish. All samples spoiled at 42 days.

In summary, concerning TVB-N, while the shelf-life of the smoked tilapia immersed in 15% salt concentration was longer than the three other groups, concerning stabilisation of lipids as well as sensorial score, storage

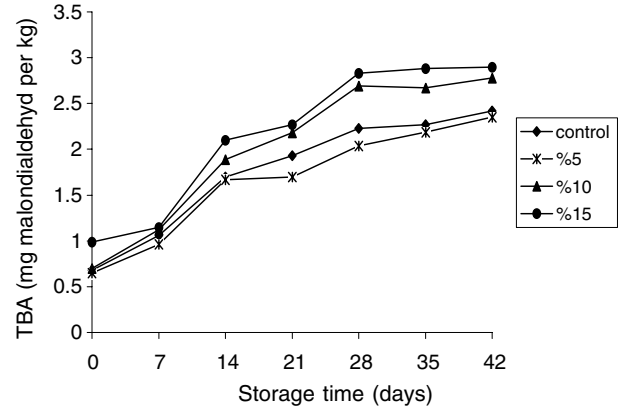

Fig. 2. TBA values of smoked tilapia brined in different salt concentrations.

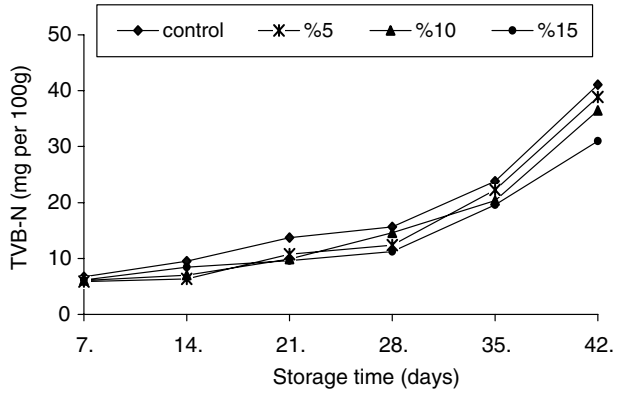

Fig. 3. TVB-N content of smoked tilapia brined in different salt concentrations.

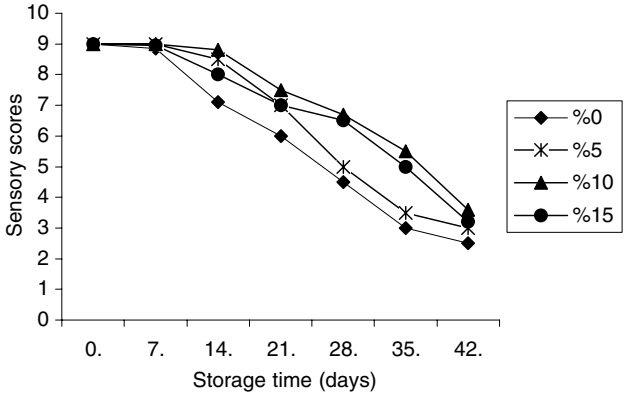

Fig. 4. Sensory scores of smoked tilapia brined in different salt concentrations.

at +4 °C with 5% salt concentration increases the shelf-life of smoked tilapia. The results of this investigation show that smoked tilapia can be stored at refrigerated conditions for over 35 days safely.

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