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Effect of processing parameters on water activity and shelf life of osmotically dehydrated fish filets

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ABSTRACT

The objectives of the study were to evaluate the effects of osmotic solution concentration on the mass transfer kinetics during osmotic dehydration and to develop a predictive model for the effect of storage temperature and a_w on the shelf life of osmotically dehydrated gilthead seabream fillets. A first degree polynomial model was chosen for the description of a_w as a function of maltodextrin concentration in the osmotic solution and processing time. A mathematical model was developed, based on a modified Arrhenius-type equation, for predicting the combined effect of temperature and a_w on the growth rate of *Pseudomonas* spp. in fish during refrigerated storage.

1. Introduction

The principle of seafood preservation by drying involves a decrease in water activity (a_w) by removal of water. By reducing the a_w of a food matrix, microbial growth is reduced or inhibited, while the rates of other deteriorative processes in the fish tissues are changed, reaching a minimum at different levels of a_w (Colligan et al., 2001; Rahman, 2006). Osmotic dehydration is a technique used to reduce a_w to improve nutritional, sensorial and functional properties of food. It is achieved by an immersion of the product into a concentrated solution of salts and/or low molecular weight carbohydrates. Difference in osmotic pressure between the food and its surrounding solution acts as the driving force for water removal, while the complex cellular structure of food acts as a semipermeable membrane (Byrne et al., 2001). The preservative effect of osmotic treatment is greater as the a_w of the final product decreases.

Spoilage of chilled fresh and minimally processed fish is attributed mainly to bacterial activity. *Pseudomonas* spp. can be the dominant spoilage microorganism in aerobic storage of fresh, chilled fish (Giuffrida et al., 2013). *Pseudomonas* spp. growth has been used as a good quality index for shelf life evaluation of aerobically stored osmotically pretreated gilthead seabream (*Sparus aurata*) fillets (Tsironi et al., 2009; Tsironi and Taoukis, 2010 and Tsironi and Taoukis, 2012). Lowering the water activity to a value below 0.95, has a pronounced effect on the growth rate of *Pseudomonas* spp. (Neumeyer et al., 1997). Under this context, osmotic treatment can extend the shelf life of gilthead seabream fillets, reducing the initial load and delaying microorganisms' growth. By developing a model that can predict the growth of *Pseudomonas* spp. in chilled fish, the rate of spoilage can be predicted for specified storage temperature and processing parameters.

Gilthead seabream (*Sparus aurata*) is a Mediterranean fish of high commercial value due to its desirable characteristics (aroma, taste, white flesh). Products like chilled fillets from marine cultured Mediterranean fish have high commercial potential if their shelf life can be extended through packaging or minimal processing. Gilthead seabream is one of the most cultured species in the Mediterranean area and its production in Greece was estimated at 60,249 tons in 2009, with Greece being the leading producer in the world with 44.3% of the total production (FAO, 2012).

The objectives of the study were to develop and validate a predictive model for the effect of storage temperature and processing parameters (time and osmotic solution concentration) on the shelf life of osmotically dehydrated gilthead seabream fillets.

2. Materials and methods

2.1. Sample preparation

Fresh gilthead seabream (*Sparus aurata*) fillets (weight: 90 ± 10 g, capture zone: Aegean Sea, Greece) directly obtained in ice from the filleting line of a mariculture unit were cut into rectangular slices ($3 \times 3 \times 1$ cm^3, 10 ± 1 g) in a laminar flow hood. Osmotic solutions were prepared by dissolving various proportions of high dextrose equivalent (DE) maltodextrin (GLUCIDEX® 47 Syrope de Glucose Dehydrate, Roquette, France). NaCl (5%) was also added

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to increase the driving force of the process and also attenuate the slight sweetness obtained during osmotic pretreatment (Lerici et al., 1985).

Sliced samples were osmotically treated in concentrated solutions of maltodextrin (40%, 50% and 60%) and 5% NaCl at 37 °C for 20, 40, 60, 90, 120, 150 and 180 min. The solution to sample ratio was 5:1 (w/w) to avoid significant dilution of the medium by water removal, which would lead to local reduction of the osmotic driving force during process (Medina-Vivanco et al., 2002). Beakers filled with pre-weighted osmotic solutions were put in a water-bath and brought up to 37 °C. Seven beakers were used for each osmotic solution (one for each sampling time). Slices were submerged in the osmotic solution by means of a grid. At the selected times of sampling, one beaker with each osmotic solution was removed from the water-bath. Samples were removed from the osmotic solution and blotted gently with a tissue paper in order to remove the excess coating solution and then weighed. Three replicate samples were removed and measured each time and the average values were taken. a_w was monitored during process using an a_w-meter (Rotronic AG, AM3 + Aw VD, Bassersdorf, Switzerland).

2.2. Shelf life kinetic study

Two replicated storage experiments were carried out with untreated and 60 min osmotically treated fish samples. Fish fillets were stored aerobically (not sealed) at controlled isothermal conditions of 0, 5, 10 and 15 °C in high-precision (±0.2 °C) low-temperature incubators (Sanyo MIR 153, Sanyo Electric, Ora-Gun, Gunma, Japan) and shelf life study was carried out. Temperature in the incubators was constantly monitored with electronic, programmable miniature data loggers (COX TRACER®, Belmont, NC). Samples were taken in appropriate time intervals to allow for efficient kinetic analysis of microbial spoilage.

For microbiological enumeration, a representative sample (10 g) was transferred to a sterile stomacher bag with 90 mL sterilized Ringer solution (Merck, Darmstadt, Germany) and was homogenized for 60 s with a Stomacher (BagMixer® interscience, France). Samples (0.1 mL) of 10-fold serial dilutions of fish homogenates were spread on the surface of Cetrimide Agar (CFC, Merck, Darmstadt, Germany) for enumeration of *Pseudomonas* spp. after incubation at 25 °C for 48 h. Total aerobic viable count (TVC) was enumerated on Plate Count Agar (PCA, Merck, Darmstadt, Germany) after incubation at 25 °C for 72 h. Two replicates of at least three appropriate dilutions were enumerated (Tsironi et al., 2009).

The microbial growth was modelled using the Baranyi Growth Model (Baranyi and Roberts, 1995). For curve fitting the in-house program DMfit of IFR (Institute of Food Research, Reading, UK) was used, kindly provided by Dr. J. Baranyi. Kinetic parameters such as the rate (k) of the microbial growth were estimated.

The sensory attributes of raw and cooked fish fillets were evaluated by a trained sensory panel of 8, selected according to ISO 8586-1 (1993) standard and trained using discriminative tests with practice evaluation methods of determining spoilage characteristics in fish fillets (Botta, 1995). Gilthead seabream fillets were cooked individually wrapped in aluminum foil, at 180 °C for 20 min, in preheated oven. The sensory parameters were evaluated using descriptive terms and recorded in appropriate forms, reflecting the organoleptic evolution of quality deterioration. An acceptance test was also conducted. Rating was assigned separately for each parameter on a 1–9 descriptive hedonic scale (9 being the highest quality score and 1 the lowest). A score of 5 of sensory acceptability was taken as the average score for minimum acceptability. Sensory parameters were plotted vs time for all treatments and temperatures studied and the apparent order of quality loss was determined based on the least square statistical fit.

2.3. Model validation at isothermal and dynamic conditions

Fresh gilthead seabream (*Sparus aurata*) fillets from a different batch were cut into rectangular slices ($3 \times 3 \times 1$ cm^3, 10 ± 1 g) and treated at 37 °C in osmotic solution, 50:5maltodextrin(DE47):NaCl/100 g for different times (0, 30, 60 and 90 min). Untreated and treated slices were aerobically packed in unsealed pouches and stored at controlled isothermal conditions (0, 5, 10 and 15 °C). The model developed from the isothermal studies was also validated at dynamic temperature conditions. A variable temperature distribution was used, that consisted of several cycles of three temperature steps: 2 h at 5 °C, 2 h at 9 °C and 2 h at 12 °C, with T_{eff} = 8.8 °C.

Pseudomonas spp. were enumerated on Cetrimide Agar (CFC, Merck, Darmstadt, Germany) in appropriate time intervals to allow for efficient kinetic analysis of microbial deterioration. The experimentally measured specific growth rates for *Pseudomonas* spp. and the shelf life of gilthead seabream fillets were compared to the values predicted by the developed mathematical model.

2.4. Statistical analysis

Analysis of variance (ANOVA) at a significance level of 95% was used for the analysis of quality degradation rates of untreated and osmotically treated gilthead seabream fillets (STATISTICA® 7.0, StatSoft Inc., Tulsa, USA). Significant differences were calculated according to Duncan's multiple range test (a = 0.05).

Mathematical model coefficients were calculated by non linear regression using SYSTAT 10.2® Software (CLECOM Software Specialists, Birmingham, UK).

3. Results and discussion

3.1. Osmotic pretreatment

Osmotic dehydration caused substantial a_w decrease with higher solution concentrations showing the strongest effect ($P < 0.05$), leading to products without the significant quality and nutritional damage, observed using traditional drying methods. A first degree polynomial model was chosen for the description of a_w as a

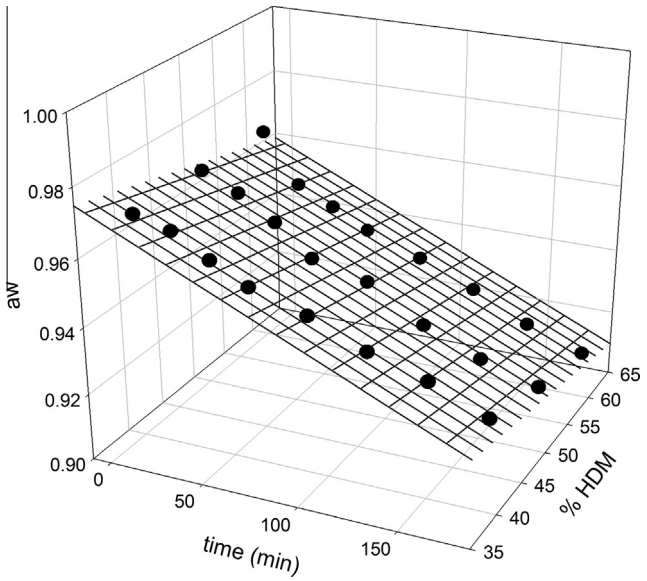

Fig. 1. Water activity (a_w) of gilthead seabream fillets after osmotic pretreatment using solutions with 40%, 50% and 60% HDM (plus 5% NaCl) at 37 °C.