Food Research International 108 (2018) 331–338

Contents lists available at ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

The influence of processing conditions on the weight change of single herring (*Clupea herengus*) fillets during marinating

Maria Helbo Laub-Ekgreen*, Brais Martinez-Lopez, Stina Frosch, Flemming Jessen

Division of Industrial Food Research, National Food Institute, Technical University of Denmark, Søltofts Plads, Building 227, Lyngby 2800-Kgs, Denmark

ARTICLE INFO

Keywords:
Herring
Marinating
Brining
Weight change
Yield
Modeling

ABSTRACT

One of the main issues in the manufacturing of marinated herring is the variation in yield, which in turn, is affected by the processing conditions and the variance in fat content. In the present work, we study these effects on individual herring fillets, with focus on the intermediate brining process. Brining time, brine concentration, marinade composition and storage time were varied. For brine concentrations 8%, 16% and 26%, the diffusion coefficient was $2.31 \times 10^{-9}\,m^2\,s^{-1}$, which was used for model development of salt change prediction in herring during brining. Conducting experiments on single fillets revealed a correlation between the fat content and the weight change after 35 days of marinating. The greatest change occurred within the first few days and only minor changes were seen during the storage period of up to one year. These results contribute to a better understanding of the herring marinating process, which can aid the optimization process in the industry.

1. Introduction

Marinated herring products are traditionally consumed in Northern European countries and manufactured by a process using a solution of salt and acetic acid in order to increase the ionic strength, and to decrease pH and hereby make the fish available for consumption most of the year (Rodger, Hastings, Cryne, & Bailey, 1984). The manufacturing of marinated herring varies from country to country; the herring fillets are submerged directly into a solution of salt and acetic acid in a typical German production, whereas in Denmark, an intermediate brining step is commonly used in the marinating process. The herring fillets are initially submerged in salt brine, then drained, and finally marinated in salt and acetic acid (Karl, Roepstorff, Huss, & Bloemsma, 1995). The marinating process affects the muscle proteins in fish, resulting in a change in the water content of the muscles, and consequently the weight change determiningthe product yield (Rodger et al., 1984). The product yield is an important aspect of profitable marinated herring production, and several factors potentially affect the product yield, such as the processing conditions and the variability of the raw material. However, little information exists about the intermediate brining in the marinating process and its effect on product yield. Studies on salt brining and how it influences product yield have been carried out for different fish species; such as cod (Barat, Rodriguez-Barona, Andres, & Fito, 2002; Thorarinsdottir, Arason, Bogason, & Kristbergsson, 2004), salmon (Gallart-Jornet et al., 2007a, 2007b) and herring (Birkeland, Sivertsvik, Neilsen, & Skåra, 2005). The effect of marinating on different quality properties has been studied for different fish species (Baygar, Alparslan, & Kaplan, 2012; Szymczak & Kołakowski, 2012; Szymczak, Kołakowski, & Felisiak, 2012; Topuz, 2016), however, these investigations did not include salt brining as an intermediate step in the marinating process and hence its effect on product yield. Studies of fish marinating have mainly been conducted batch wise (Birkeland et al., 2005; Szymczak & Kołakowski, 2012; Topuz, 2016), where it is often assumed that batches are homogenous groups, even though it is well known that variation within batches does occur. The fat content, which is often regarded as an important quality parameter for herring products varies substantially in herring fillets (Karl & Münkner, 2002). This can be due to the mixing of stocks and an uneven age distribution of the herrings within catches (Lane, Westgate, & Koopman, 2011; Nielsen, Hyldig, Nielsen, & Nielsen, 2005; Rajasilta, 1992). Moreover, there is also a seasonal variation in fat content due to changes in feed availability and water temperature. In addition, the fat content also follows the cycle of sexual maturation (Aidos, van der Padt, Luten, & Boom, 2002; Nielsen et al., 2005; Szlinder-Richert, Usydus, Wyszyński, & Adamczyk, 2010; Timberg, Koppel, Kuldjärv, & Paalme, 2011). Lastly, yearly differences in the fat content also occur (Aidos et al., 2002; Lane et al., 2011). Investigating the herring marinating process at batch level without taking the variation within the batch into account results in loss of valuable information concerning the effect of the biological variation in fat content on the process yield. In order to uncover the relation between process parameters, product yield and the raw material properties, it is therefore necessary to conduct studies at the level of

* Corresponding author.
E-mail address: mheek@food.dtu.dk (M.H. Laub-Ekgreen).

https://doi.org/10.1016/j.foodres.2018.03.055
Received 9 January 2018; Received in revised form 17 March 2018; Accepted 18 March 2018
Available online 23 March 2018
0963-9969/

Nomenclature

M_t	sample weight at time t (g)
M_0	initial weight of sample (g)
ΔM_t	weight changes of sample (w/w)
$\Delta M_{w,\ t}$	weight change of water (w/w)
$x_{w,\ t}$	weight fraction (w/w) of water in herring at time t
$x_{w,\ 0}$	initial weight fraction (w/w) of water in herring
wps	water phase salt (g/100 g water)
φ	osmotic coefficient
ν	number of NaCl ions
α	volume ratio of solution and herring fillet
q_n	non-zero positive roots of the transcendental equation
M_w	molar weight of water (kg/mol)
m	molality of NaCl in the solution (mol NaCl/kg H_2O)
L	characteristic dimension of the system (m)
$D_{App,s}$	apparent diffusion coefficient of salt in the water phase ($m^2\ s^{-1}$)
a_W	water activity
C_{wps}	salt concentration in water phase (kg salt ·(kg salt + kg $H_2O)^{-1}$)
$C_{wps,\ \infty}$	salt concentration in water phase in herring when in equilibrium with brine (kg salt·(kg salt + kg $H_2O)^{-1}$)
$C_{sb,\ 0}$	initial brine concentration (kg salt·(kg salt + kg $H_2O)^{-1}$)
$C_{sb,\ \infty}$	salt concentration in the brine in equilibrium with water phase of herring (kg salt·(kg salt + kg $H_2O)^{-1}$)

individual herrings. For that reason, the present study is unique, as the herring fillets were tagged and followed individually through the brining and marinating processes, which makes it possible to study the relation between the total fat content, the process parameters and the final yield.

A better scientific understanding of the marinating process at industrial level will make it possible to optimize the process, resulting in a better utilization of the raw material, a decrease in product loss and a higher financial outcome. The current processes used in industry are based on hands-on experience and knowledge passed on from previous employees, and not on a scientific understanding of the raw material and the process parameters (Voskresensky, 1965). Based on laboratory scale experiments, our aim was to investigate and explain the underlying mechanisms for the varying weight yield (outcome) of marinated herring products, with focus on the effects of the salt brining process. An additional outcome was also to provide a mathematical tool to model the brining process, that can be used for practical applications and assist the optimization process in the industry without the need of great computing power.

2. Material & Methods

2.1. Raw material and experimental design

Fresh herring butterfly fillets (*Clupea harengus*) were obtained from Skagerak Pelagic a/s (Skagen, Denmark). The fish were caught during different seasons (April, June and December) over a timespan of four years (2013–2015 and 2017). The fish were gutted, filleted (butterfly fillets), and immediately stored on ice in polystyrene boxes at 2 °C, then shipped to DTU, Lyngby, where the experiments were conducted within 2–3 days of arrival. The fresh butterfly fillets (with skin) were separated into two fillets; one fillet was numbered with a plastic tag using a fish-tagging gun (Avery Dennison, Mark III Pistol Grip Tool no. 10651) in order to track the weight of each individual fillet, and the other part of the butterfly fillet was frozen down (−40 °C) for chemical analysis of the fat content in the raw material.

2.2. Preparation of brine and marinade

Salt brine, defined as a solution of sodium chloride (referred as salt) in water, was prepared for the salt brining process of herring fillets. Saturated brine (26.5%) was prepared by dissolving 36 g of NaCl (salt) (Food-grade vacuum salt, ESCO, Hannover, Germany) per 100 g of water,to be used as a stock solution for brines with the concentrations of 8%, 13.6%, 16%, and 26% salt. Marinades, defined as a solution of acetic acid and salt (from the saturated stock solution) in water,were used for the herring marinating process. Marinades were prepared with varying concentrations of acetic acid and salt, the exact concentrations of which are specified in the text (Sections 3.4–3.6). The solutions were stirred and left overnight at 2 °C to ensure complete dissolution of the salt.

2.3. Brining

The fresh herringfillets were randomly divided into three groups, and brined in 8%, 16% or 26% salt solution with a brine-to-fish ratio of 1:1 for 24 h. At each sampling time, fillets were drained for 1–2 min using a sieve; two individual brine samples (app. 15–25 ml brine/marinade) and three fillets were taken from each bucket. Upon analysis, the brine was centrifuged at 3838 ×g for 20 min at 5 °C to remove tissue parts and insoluble matter, and kept at −40 °C until analyses were carried out. Herring fillets were rinsed under running water - in order to avoid excess salt crystals on the flesh surface - before the chemical analysis were carried out. In the brining experiment, sampling occurred every hour during the 24 h of storage.

2.4. Brining and subsequently marinating

The butterfly fillets were randomly divided into groups and brined in a solution of 13.6% salt with a fish-to-brine-ratio of 1:1 (brining times are specified in the text) to simulate industrial settings. After the brining procedure the fillets were drained in a sieve and marinated in a solution of acetic acid and salt, with a fish-to-marinade ratio of 1:1 (the concentration of salt and acetic acid is specified in the text). All experiments were carried out at 2 °C. A part of the raw herring fillets were frozen for 2 months at −40 °C prior to marinating.

2.4.1. Registration of weight changes

The fillets were collected on a grid, which allowed the brine/marinade to drip off for 1–2 min before weight registration. The individual weight of the same 2–30 herring fillet was registered at each sampling time during the experimental run, which varied depending on the experimental set-up (specified in the figures). The change in weight and water is defined by Eqs. (1) and (2), respectively.

$$\Delta M_t = \frac{M_t - M_0}{M_0}\,[-] \tag{1}$$

$$\Delta M_{w,t} = \frac{M_t * x_{w,t} - M_0 * x_{w,0}}{M_0 * x_{w,0}}\,[-] \tag{2}$$

The weight change (ΔM_t) is defined as the difference between the weight at every time point divided by the initial weight (Eq. (1)), and the weight change of water ($\Delta M_{w,\ t}$) is defined as the difference in water content at every time point divided by the initial water content (Eq. (2)). M_t is the mass in grams at time t, M_0 is the mass in grams at t = 0 (fresh), $x_{w,\ 0}$ is the weight fraction of water at t = 0 and $x_{w,\ t}$ is the weight fraction of water at time t.