Available online at www.sciencedirect.com
ScienceDirect
Journal of Food Engineering 83 (2007) 267–276
JOURNAL OF FOOD ENGINEERING
www.elsevier.com/locate/jfoodeng

Application of the SAFES (systematic approach of food engineering systems) methodology to salting, drying and desalting of cod

A. Heredia *, A. Andrés, N. Betoret, P. Fito

Institute of Food Engineering for Development-Department of Food Technology, Polytechnic University of Valencia, Camino de Vera s/n, 46022 Valencia, Spain

Available online 23 February 2007

Abstract

SAFES methodology was applied to cod process where three matrix of changes were defined corresponding to the three main stages of the process. Due to insufficient experimental data to completely build the matrix, some related hypotheses were necessary.

Specifically, this process consisted of: osmotic dehydration in saturated brine, followed by a drying at 15 °C and desalting by immersion in tap water of cod fillets. During all of which, mass transfer (basically salt, water and protein) occurs by diffusion. A migration of water from extra-intracellular liquid to solid matrix and to external fluid took place in the salting and drying stages. On the other hand, an intake of salt occurred during the process and an amount of it precipitated. However, it was observed that there was a tendency for the opposite to occur in the desalting operation.

Moreover, important changes related to protein component were taken into account. During salting, some proteins from raw cod (60%) were denatured (made soluble) due to the high ionic forces in the media. Soluble proteins above mentioned suffered a further precipitation during the drying process and a re-solubilization.

Keywords: SAFES; Cod; Salting; Drying; Desalting

1. Introduction

Salt-cured cod (*Gadus morhua L.*) is a highly appreciated and traditional product due to its excellent storage stability, sensorial properties (lightness value (L^*), texture), and nutritional value (protein content). It is widely consumed in Spain, Portugal and Latin America, although the largest producers are the North Atlantic countries, such as Norway and Iceland (Bjornsson, 2000). These two countries exported over 40,000 tonnes of salted cod to the largest cod consuming countries in 1999, which shows the importance of the product in economic terms (Gallart-Jornet, Rodríguez-Barona, Barat, Andrés, & Fito, 2003).

The traditional description of food processing is prone to simplification with possible information loss as a consequence. Food is usually considered as a homogenous fluid composed of one or two phases and of two or three components, where the classic phenomena of thermodynamic and kinetic transport are validated. The obtaining of salted, dried and desalted cod has been approached as a process composed of three unitary operations (salting, drying and desalting) where two major components flow through the cod structure: salt and water. In this typical description, no distinction was made between the apportionment of water (free and bonded water or the compartmentalization between liquid phase in cells) in relation to sensorial attributes (juiciness, firmness, colour) and stability of the product (composition of solid matrix and extracellular and intra-cellular liquid phase), the possible denaturation of proteins has not been studied enough (new con-

* Corresponding author. Tel.: +34 96 387 36 51; fax: +34 96 387 73 69.
E-mail address: anhegu@tal.upv.es (A. Heredia).

0260-8774/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jfoodeng.2007.02.025

figuration and losses) and the aggregation state of salt was not evaluated during the different stages of the process.

The new methodologies attempt to describe the real complexity without leaving out information even if some simplifications are necessary in order to model the system. In this way, SAFES (Systematic Approach of Food Engineering Systems) is a useful methodology which attempts to clarify the complex system using the simplest models applicable without loss of relevant information.

The main objective of this study was to apply the SAFES methodology as an approach to cod processing with the purpose of explaining the changes in the product's properties through complex unitary operations with minimum simplifications.

2. Materials and methods

2.1. Materials

The manufacturing of cod is an important industrial process based on three main stages (Fig. 1a): osmotic dehydration (OD) carried out using a saturated brine solution at 5 °C during 15 days, followed by air drying (AD) in an chamber at 15 °C with air velocity of 1.2 m/s and an air relative humidity ranging from 50% to 65% until the moisture content of the dried cod reaches 47%. Finally, desalting (DS) using a ratio of cod: water 1:9 (w/w) at 5 °C during 24 h.

Salting is one of the oldest treatments used in food preservation and it consists of transporting salt into food structures while water flows out of them. There are several

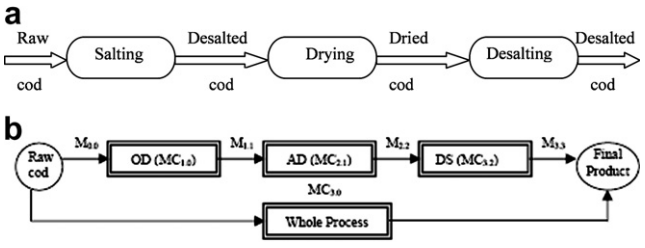

Fig. 1. Diagrams of the salting, drying and desalting of cod: (a) Traditional flux diagram ($N = 3$) and (b) Diagram of whole process including SAFES nomenclature for each stage (MC = matrix-changes; M = matrix's product) ($N = 3$).

advantages to brining: higher weight yield (Beraquet, Iaderoza, Jardim, & Lindo, 1983; Bogason, 1987) caused by uptake of water; protection against oxidative rancidity (Wheaton & Lawson, 1985); and faster salting due to a higher rate of salt penetration in the fish muscle (Akse, Gundersen, Lauritzen, & Ofstad, 1993). Nevertheless, this process is not possible to obtain a stable product and a further drying treatment is required, the objective of which is to drastically reduce water. Traditional method consists of solar drying but it is slow and extremely dependent on climatic conditions making development of industrial methods necessary (Ismail & Wootton, 1982). Although in this case a_w, it is the same before and after drying, the latter is a very important process from the preservation point of view as the excess of solid salt can be considered as a reservoir in the case of water gaining during storage at an atmosphere of relative humidity higher than 75% (Andrés, Rodríguez-Barona, Barat, & Fito, 2005).

The process ends with the direct consumption of either salted cod or previously desalted cod (under tap water).

On one hand, unitary operations during the processing of cod have been studied in general terms, taking into account one or two major components: mainly salt and water (Andrés et al., 2005; Collignan & Raoult-Wack, 1994). On the other hand, literature revealed numerous specific studies in which one component and its interaction with external media was investigated but neither its aggregation state nor its migration in food systems between phases were investigated. The investigation of proteins has been based on the effect of brine composition and pH (Martínez-Alvárez, 2003), changes in myofibrillar proteins during processing of salted cod (Thorarinsdottir, Arason, Bogason, & Kristbergsson, 2002), or on the effects of the hydration process on water–soluble proteins (Luccia et al., 2005). Studies on product quality have emphasized the influence of additives (Esaiassen et al., 2005 and), freshness (Barat et al., 2006) catching methods (Esaiassen et al., 2004) or state of *rigor* and freezing (Lauritzsen et al., 2004) and on sensory quality and consumer preference.

2.2. Methods

SAFES methodology (Fito, LeMaguer, Betoret, & Fito, 2007) allows the analysis of the migrations of components between phases and of their aggregation state (Table 1)

Table 1
Phases, components and states of aggregation in cod system

PHASES	j	COMPONENTS	i	STATES OF AGGREGATION	k
Solid Matrix	1	Water	1	Liquid	1
Liquid extracellular	2	Non soluble solids (native)	2	Adsorbed	2
Liquid intracellular	3	Native soluble solids	3	Rubber	3
Soluble solids (solid)	4	NaCl (added soluble solids)	4	Vitreous	4
Solid fat	5	Fat	5	Crystal	5
Liquid fat	6	Whole food	0		
Whole Food	0				
External fluid	7				