

Cost Optimization in Batch Industrial Salami Ripening through Mathematical Modeling

Giovanni Cascone, Michele Miccio, Carlo Diaferia, Massimiliano Dodaro, Michela Fraganza, Franco Longo, Lucia Seta

Abstract — Within a recent research project (PON Safement) devoted to “innovative” fresh and fermented meat-based products, the project partners’ chambers were used for salami ripening and a number of experimental tests were carried out under strictly controlled conditions. In addition to both process and product data obtained during ripening, the PON Safement has also allowed focusing on production cost data. Therefore, a mathematical model was developed to express costs associated to the industrial batch ripening of salami and an objective function was devised with the goal of optimization.

The model considers the cost of raw materials, the operating costs (linearly increasing with time during maturing) and, finally, a cost for the “loss of quality” of an off-specification product, expressed as a “non-revenue” and referred to as “QL factor”. The objective function is a nonlinear function of the non-dimensional time t^* .

Two test cases have been constructed by considering Italian traditional sausage products, i.e., the spicy “Soppressata A” produced by Dodaro SpA and the “Salame di Felino”, and the corresponding results have been analyzed and compared. The outcome of this work is interesting at present and promising in the future for further development and validation activities.

Keywords — Ripening chamber, Salami, Mathematical Model, Optimization

1. Introduction

Salami are dried and fermented meat-based food that are traditionally consumed in different areas of the world. They are commonly investigated in food science and technology (e.g., Katz and Seinsky, 1987) as well as in engineering design, modeling and simulation (Grassi and Montanari, 2005; Cascone et al., 2015; Cascone et al., 2017).

The largely prevailing process in the salami production from fresh sausages is dehydration. The final product weight loss is high enough, generally about 1/3 of the initial weight, 20% of which is in the first processing week (Diaferia et al., 2011). The whole sausage ripening process consists of a sequence of phases, as the following (Zambonelli et al., 1992):

- **1st phase: stabilization** of the introduced product. Chamber temperature: 5-7°C. It is aimed at obtaining a uniform product temperature, before start-up of the drying process. This phase is used only if the product loading time in the chamber is high and so it is necessary to avoid initial temperature differences.
- **2nd phase: low temperature drying** at 7-8 °C. This phase allows a weight loss of 2% in 12-20 hours and

guarantees drying of the casing, which are very moistened because just washed. Only a few producers are equipped and actually adopt this phase.

- **3rd phase: heating**. In this phase the product attains a core temperature of about 18-20°C; the duration of the heating stage is a function of the chamber temperature, the sausage size and shape and the meat quality. A small weight loss is allowed by controlling the chamber relative humidity (RH). In this phase, temperature and a high humidity facilitate the sausage typical fermentation, which will give the distinctive taste and characteristic flavor.
- **4th phase: actual drying**. A strong dehydration and a drop in the chamber temperature characterize this phase, which results in the end of the above said fermentation. Beginning temperature: 18-22°C, RH: 50-75%.
- **5th phase: ripening**. This phase is a drying phase too, but at a milder rate. The chamber temperature decreases from an initial value of 17°C down to 12-13°C; RH is about 55-85%.

Fully automated operation of the ripening chamber ensures uniform circulation of curing air within the volume occupied by sausages inside the chamber.

Within a recent research project (PON Safement) aimed at the development of “innovative” methods for the production of low-fat, fresh and cured meat products, with the addition of functional starters, a well-structured experimental program was carried out. For salami ripening, the project partners’ chambers were used under strictly controlled conditions, including the pilot-scale, air ascending-flow cell of the Experimental Station for Food Preserving Industry (SSICA) at Parma (IT). In addition to process and product data obtained during ripening, the PON Safement project allowed focusing on production cost data, too. This triggered the idea of developing a mathematical model of costs associated to the industrial batch ripening of salami with the goal of optimization.

Optimization with mathematical models of industrial salami ripening is not very much treated in literature. Tradition and rules of thumb hold, whereas many actions and decisions are taken by process technologists on the basis of his personal experience and historical data (e.g. Imre and Kornycy (1990) elaborated a dynamic drying algorithm for salami and set up an automatic ripening control strategy. Bertolini et al. (2006), based on previous modeling works for the fluid-dynamic and thermal simulation of the above SSICA pilot cell (Grassi and Montanari, 2005), simulated and validated the batch ripening process for different salami. In addition, from the analysis of

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award sessions The theme of the conference and its proceedings is Impact on People Business and Society **Revenue Management and Survival Analysis in the Automobile Industry** André Jerenz,2008-08-01 Andr Jerenz develops a price based revenue management framework to support retailers in establishing better and more profitable pricing strategies including assigning an initial asking price and the adjustment of price over time *Economic Evaluation and Investment Decision Methods* Franklin J. Stermole,1982 A Bridge Between Control Science and Technology: Manufacturing, man-machine systems, computers, components, traffic control, space applications International Federation of Automatic Control. World Congress,1985 **A Bridge Between Control Science and Technology** International Federation of Automatic Control. World Congress,1985 **Proceedings of the ... ASME Design Engineering Technical Conferences** ,2000 *DETC2005* ,2005 **Multidisciplinary Research Area in Arts, Science & Commerce (Volume-2)** Chief Editor- Biplab Audhya, Editor- Dr. Jasmina B.Solanki, Dr. M. Maria Sherine Sweeja, Dr. Devimeenakshi K, Dr. Nagaraj G U, Dr. Anushka Gkl Jain, Haridasan L,2025-06-09 **Proceedings** ,2002 **Applied Calculus for Business, Economics, and the Social and Life Sciences, Expanded Edition** Laurence Hoffmann,Gerald Bradley,Dave Sobecki,Michael Price,2012-01-06 Petroleum Abstracts ,1993 Applied Management Science John A. Lawrence,Barry A. Pasternack,1998 This text aims to show students how to use the management science results in actual managerial decision making It focuses on real world applications and software rather than straight mathematics It should prepare students for the challenging situations faced by management scientists every day as they gain a familiarity with current management science approaches build skills in quantitative decision making improve their overall knowledge of business improve communication skills and develop a strong familiarity with relevant computer programs Proceedings, Annual Convention Natural Gas Processors Association,1988 A First Course in Mathematical Modeling Frank R. Giordano,Maurice D. Weir,1985 Shows students how to use fundamental mathematical concepts in a modeling framework to investigate practical problems from many academic disciplines

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