Journal of Food Engineering 222 (2018) 162–168

Contents lists available at ScienceDirect

Journal of Food Engineering

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

Positive effects of sequential air ventilation on cooked hard Graviera cheese ripening in an industrial ripening room

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ARTICLE INFO

Article history:
Received 11 September 2017
Received in revised form
13 November 2017
Accepted 16 November 2017
Available online 17 November 2017

Keywords:
Cheese ripening
Ripening room
Sequential ventilation
Power consumption
Mass loss
Graviera cheese

ABSTRACT

An industrial ripening room used for Graviera cheese ripening was equipped in order to compare Continuous Ventilation (CV: full time air circulation) and Temperature based Sequential Ventilation (TSV) processes. Under controlled temperature and Relative Humidity of the ripening room, three reference 30-day ripening trials performed in CV mode were compared to three similar trials performed in TSV mode. TSV was monitored between 2 temperature set points. When the lower one (16 °C) was reached, ventilation was stopped; when the higher one (16.8 °C) was reached, ventilation restarted. Power consumption, cheese mass loss and cheese quality were determined as comparison criteria. The use of TSV involved important reductions on ventilation time (48%), energy consumption (42%), cheese mass loss (0.9%) leading to a positive impact on the economy of the ripening process. Additionally, as shown by microbiological, physicochemical and sensory analyses, TSV neither had negative nor significant positive effects on cheese quality.

1. Introduction

Cheese ripening is the last stage of the cheese making process. It plays a decisive technological role because it involves the evolution of complex biochemical reactions, such as glycolysis, proteolysis, lipolysis and flavor formation (Beuvier and Buchin, 2004; Fox, 1989; Mc Sweeney and Sousa, 2000). Cheese flavor results of a complex balance among volatile and non-volatile chemical compounds from milk fat, proteins and carbohydrates during ripening (Mariaca et al., 2001; Urbach, 1997).

Several cooked hard, fully ripened cheeses are traditionally produced in Greece from raw, thermized or pasteurized ewes' and goats' milks; Graviera is the most popular of them (Litopoulou-Tzanetaki and Tzanetakis, 2011; Samelis et al., 2009). The manufacturing process and the main technological, microbiological, physicochemical and sensory characteristics of Graviera cheese are reported in the Hellenic Code for Food and Beverages (Anonymous, 2014) and recent studies (Noutsopoulos et al., 2017; Samelis et al., 2010). Particularly as regards the ripening process, the fresh Graviera cheese molds after brining are traditionally ripened on wooden shelves in air-ventilated rooms at 12–18 °C and 85–95% RH for 90 days, depending on the PDO cheese variety. Recent advances in the industrial cheese processing equipment and the increasing usage of pasteurized milk and commercial starter cultures has enabled Greek manufacturers to ripen Graviera cheeses at 16–20 °C for 30 days, followed by 'cold' (4 °C) ripening under vacuum packaging for up to 90 days, thereby increasing the cheese yield (Samelis et al., 2009, 2010).

In general, traditional artisanal cheeses were ripened naturally in cool, moist and physically ventilated places, such as caves and cellars, without control of the environmental conditions. Following industrialization of cheese production, ripening takes place in large rooms whose temperature and relative humidity (RH) are controlled automatically (Mirade et al., 2012). Continuous ventilation (air circulation) ensuring homogeneity in the industrial ripening rooms is generally performed. The need to continuously operate and control them has increased the expenditure on cheese ripening, which turns to be the most energy demanding cheese process operation. Another consideration is the ripening time which depends on the cheese type and technology (Fox, 1989). The longer the duration of ripening, the higher is the energy

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https://doi.org/10.1016/j.jfoodeng.2017.11.021
0260-8774/

consumption. Optimization of ripening is essential to save energy and increase cheese yield while preserving cheese quality.

Temperature is acting directly on the growth rate and biological activity of the cheese ripening microbiota. Increasing the temperature is one of the easiest ways to accelerate ripening (Leclercq-Perlat et al., 2012). However, an important increase of the ripening temperature involves the risk of significantly modifying the cheese microbiology, biochemistry and sensory quality (Kujawski et al., 2003). The RH of the ripening room atmosphere, which is controlled according to the type of cheese, affects cheese rind water activity (a_w) and water losses (Leclercq-Perlat et al., 2012; Macedo et al., 1997; Mirade et al., 2004; Simal et al., 2001). Cheese mass loss (water removal) also is a very critical parameter affecting the yield of the cheese making process, and should be limited to what is essential to preserve cheese quality during and after ripening. Apart from the temperature and mainly RH, air ventilation affects the cheese mass loss during ripening; however, its role is complex and remains little quantified.

Ventilated air circulation allows the removal of the heat and moisture emitted by the cheeses, determines water loss of the cheeses and gas concentration in the atmosphere. The energy costs linked to ventilation and air conditioning were estimated to vary in a large range, from 30 to 60% of the total costs of the ripening as a function of the type of ripened cheese and its ripening time (Arcadis IMD report, 2000; cited by Xu et al., 2009; Dr. Mirade Sylvain, personal communication). In order to reduce the energy consumption, the concept of sequential ventilation was proposed by Picque et al. (2009) and studied at pilot plan scale (ripening room of 12.3 m^3). With a ventilation time limited to one third of the ripening time, a reduction in energy consumption of approximately 20% was reported. Sequential ventilation was also applied on a 1290 m^3 ripening room in which PDO Saint Nectaire cheeses were ripened for four weeks (Corrieu et al., 2010; Mirade et al., 2012). Comparative ripening trials were performed with Continuous Ventilation (CV), ‘time-based’ and ‘temperature-based’ sequential ventilation. The best results were obtained for ‘temperature-based’ sequential ventilation (TSV) with an economy close to 50% of the electrical power consumption. Results further showed that sequential ventilation did not significantly affect the microbiological, physicochemical and sensory characteristics of the ripened cheeses. Consequently, sequential air ventilation is promising for reducing energy consumption during cheese ripening (Corrieu et al., 2010; Mirade et al., 2012).

No published research studies on monitoring of the Graviera cheese ripening conditions, particularly air circulation, exist. This study was therefore undertaken (i) to describe the performance of ‘temperature-based’ sequential ventilation in an industrial ripening room used for Graviera cheese ripening; (ii) to quantify the positive effect of sequential ventilation on energy consumption and cheese mass loss; (iii) to determine the changes due to sequential ventilation on Graviera cheese quality.

2. Materials and methods

2.1. Graviera cheese manufacture and ripening

Graviera cheese molds (35 cm diameter; 13–14 cm height; 13–15 kg each) were manufactured from thermized (63 °C for 30 s) ewes' milk in a traditional dairy plant (Skarfi, Filippiada, Greece). After thermization, the milk (3000 L) was cooled at 34 °C. A freeze-dried concentrated starter culture (reference GRU IDC 01, CSL, Lodi, Italy) involving a blend of *L. lactis* subsp. *lactis*, *L. lactis* subsp. *cremoris*, *L. lactis* subsp. *lactis* biovar *diacetylactis, Leuconostoc mesenteroides* subsp. *cremoris* and *Streptococcus thermophilus* strains was added to the milk in order to reach 6 log cfu/ml of starter bacteria. All other ingredients were then added in accordance with a standard manufacturing protocol (Noutsopoulos et al., 2017), with the rennet last, followed by standard milk curdling (at 34 °C for 35 min) and curd cutting, cooking (at 42 °C for 48 min), molding, pressing, holding (at 18 °C for 24 h), brining (immersed in 20% brine at 12 °C for 5 days) and draining (at 12 °C for another 24 h) operations. On day-7, the brined cheeses were transferred to the industrial ripening room. After “hot” ripening at 16–17 °C for 30 days, the cheese molds were vacuum packaged and their “cold” ripening was continued at 4 °C for up to 90 days.

2.2. The industrial ripening room

The surface and the volume of the industrial ripening room used for Graviera ripening are 79 m^2 (9.3 × 8.5 m) and 340 m^3 (4.3 m height), respectively. As shown schematically in Fig. 1, the ripening room was equipped with 2 air treatment units (AT) insuring air circulation and conditioning (temperature and relative humidity), 4 lanes (L), separated by 3 corridors (C), with 7 or 8 selves (S) each. Graviera cheeses are placed on the selves. The maximum capacity of the ripening room is close to 2100 cheeses, but generally only half capacity was used (around 1000 cheeses).

Dry (Td) and wet (Tw) temperatures were measured with Pt resistances (1000 Ω at 0 °C). Td was used for the measurement and control of the ripening temperature by heating or cooling the air flowing inside of the air treatment units. The difference between Td and Tw allowed the calculation of the ripening room relative humidity (RH) using simple mathematical functions according to the Carrier Psychrometric Chart.

A wireless sensor (LEM reference EMN100-W4, Distrame, Maisons-Alfort, France) was measuring the whole ripening room electrical power consumption. The sensor values were obtained every 5 min and integrated from the beginning to the end of each ripening trial in order to get the total electrical power consumption. The total consumption of the four main devices insuring CV or TSV (the fan for air circulation, the cooling machine, the cooling pump, the air heater) were obtained thanks to their information status (On or Off) available in real time through the ripening room control system.

A software (iCRIC, IDDN.FR.001.500008.000.R.C.2015.000.30600) especially developed was in charge of the ripening room monitoring and control, including key functions as data acquisition, display and storage, ventilation management, temperature and RH controls.

In order to study the progressive cheese mass losses following water removal versus ripening time, four cheese molds, distributed in standard shelve locations around the ripening room as shown in Fig. 1 by the arrows A, B, C and D, were weighed manually at the beginning and the end of ripening. Apart from the effect of TSV, the manual weighing process allowed to realize potential location-dependent variations in the cheese mass loss. In parallel to manual weighing, an electronic balance (Precisa 320XB, Pesage Normandie, Igoville, France) placed in a constant position inside the ripening room (B), was used (Fig. 1). For each CV or TSV trial, one standard cheese mold was kept loaded on the balance for 30 days, and its decreasing mass was recorded with the iCRiC software during ripening.

2.3. Trials performed and sequential ventilation set up

To study the ventilation effect, six Graviera cheese 30-day hot ripening trials were performed. Three were reference trials ripened under CV and three were ripened under TSV monitoring conditions (Table 1). As it was impossible to manage in parallel CV and TSV ripening trials in one industrial room available at Skarfi, separated trials were performed. To limit the effect of milk seasonal changes,