Influence of ripening conditions on Scamorza cheese quality

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Abstract: Scamorza is a pasta filata cheese produced in Southern Italy and eaten after a short ripening. The ripening phase is critical in defining the main qualitative features of the Scamorza cheese. The success of this operation is conditioned not only by the process parameters, but also by the characteristics of the ripening room in which different microclimates originate. This work intended to evaluate the influence of the different positions of cheeses within the ripening room on the evolution of their qualitative characteristics during the process of drying/ripening. For this purpose, samples of Scamorza cheese, produced in the Molise Region (Italy), were divided into two batches (C and L) and subjected to ripening for seven days in a thermo thermo-regulated room. The two batches were placed in different points of the room: the batch C in the central area and the batch L in the lateral area. During the ripening, temperature, humidity and air flow were monitored and the Scamorza cheeses were analysed to assess some qualitative characteristics. In a ripening room, the created microclimates are able to influence the quality of the product, as demonstrated by data related to temperature, humidity and air flow. In fact, from the results obtained, some appreciable differences among products from batches C and L were observed for the weight loss, the water activity and the colorimetric indexes. Differences in the behaviour of mesophilic lactic acid bacteria, pH and acidity were also found. The more rapid loss of water, characterizing the batch C, resulted in an evolution of physicochemical, physical and microbiological features, which resulted different from those observed in the samples from the batch L. Therefore, the results obtained in this study point out that, within the ripening room, the formation of different micro-environments is able to strongly influence the definition of the qualitative characteristics of the products placed in it.

Keywords: pasta filata cheese, ripening, drying, cheese quality, Lactic acid bacteria, air flow, ripening room
DOI: 10.3965/j.ijabe.20130603.009

Citation: Sorrentino E, Tipaldi L, Pannella G, La Fianza G, Succi M, Tremonte P. Influence of ripening conditions on Scamorza cheese quality. Int J Agric & Biol Eng, 2013; 6(3): 71－79.

1 Introduction

The "pasta filata" cheeses, because of their unique characteristics and charm of tradition, are one of the most popular dairy products of Southern Italy. They can be differentiated into many varieties, depending on the area and the technology of production and the milk used[1].

One of the best-known pasta filata cheeses produced in Molise, a region of Southern Italy, is "Scamorza"[2]. It is produced by using thermised cows' milk, then coagulated at 36-38℃ by using calf rennet. A natural whey culture or a selected culture may be used as a starter. After cutting and removal of the whey, the curd is less ripened until the pH value suitable for stretching in hot water is reached. The cheese is pear-shaped (weight about 200 g) and it is salted by immersion in brine. This unique shape is given by tying together two Scamorza cheeses which then are hung during the ripening process. Scamorza is subjected to a brief drying (maximum 24 hours) then consumed fresh, or smoked, or ripened for few days. At an industrial-scale production, pasta filata

Received date: 2013-04-01 **Accepted date:** 2013-06-17
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cheeses are usually ripened at about 12-16℃ and under 85% relative humidity (RH), for a variable time, depending on the cheese to be obtained[3], while in small local industries, the traditional ripening of pasta filata cheeses still occurs in refrigerated chambers (about 15℃), without controlled air flow and RH levels[4].

The ripening is one of the most important steps in the cheese making process. It is characterised by the development of a microbial consortium whose activities, especially in long ripened pasta filata cheeses, are responsible for important biochemical and physicochemical changes that occur on the surface and at the core of the curd as a function of the ripening time[5]. This phase is dominated by lactic acid bacteria (LAB), whose enzymes play a determining role in developing the characteristic flavour of the cheese. In pasta filata cheese, the most represented LAB are mesophilic lactobacilli, which obtain an advantage over the thermophilic species due to the low temperatures used during the ripening process[1]. Mesophilic lactobacilli, which usually derive from the milk, are also called Non Starter Lactic Acid Bacteria (NSLAB). They are characterised by a very rich and varied enzymatic equipment, but also by a lower acidifying activity than that of thermophilic LAB, which generally represent the main microbial constituent of starter cultures used in the production of pasta filata cheeses.

During the ripening process an important loss of water occurs[6], and water is vaporised from the wet surface of the cheese to the air stream. At the same time, the water diffuses from the interior of the solid towards the surface[7]. Water diffusion also affects the growth of bacteria and moulds, since the superficial water activity, which strongly affects the development of the microbial consortium, is determined by the balance between water evaporation and the internal movement of water to the surface[8].

Microbial activities and physicochemical changes responsible for the organoleptic characteristics of cheeses are influenced by the climatic conditions of ripening rooms[9]. If drying is carried out in uncontrolled conditions of temperature and humidity, as often happens in small dairies producing Scamorza cheese, a negative trend in biochemical phenomena during the ripening process can be observed, with the consequent decay of qualitative cheese characters[10]. So to get a controlled evolution of the cheese ripening process, with a positive influence on the weight loss of the cheese and a reduction of the ripening time, it is essential to work under controlled conditions of temperature and humidity.

In order to set up the optimisation of the ripening process of cheeses, different studies have been made on the relationship between ventilation, indoor atmosphere and quality of the product, highlighting heterogeneity in the distribution of climatic conditions and, consequently, differences in the ripened cheeses in terms of mass and water loss and of diffusion of water and salt[5,7,9,11]. This heterogeneity of climatic conditions during the ripening may also strongly influence the sensory characteristics of the cheese[12], so that cheese-makers have to regularly move the cheeses into the ripening room in order to achieve even water losses and uniform appearance of the cheese surface[10,13].

Few data have been published on the influence of the climatic conditions during the ripening on the microbiological characteristics of the cheeses. Based on previous considerations, this work intended to study the evolution of physicochemical and microbiological features of Scamorza cheeses during the ripening process in an experimental ripening room. In particular, possible differences in the quality of Scamorza cheeses as a function of their positions in the ripening room were investigated.

2 Materials and methods

2.1 Samples

The cheese making process was carried out in a local dairy industry (“Caseificio Molisano L. Barone s.n.c.”, Vinchiaturo, CB, Italy) as described by Niro et al.[4]. Briefly, pasteurised milk was inoculated with a commercial starter mix (1U/hL) composed by *Streptococcus thermophilus*, *Lactobacillus helveticus*, *Lb. delbrueckii* ssp. *bulgaricus* (Clerici-Sacco Group, Cadorago, Italy) and added with commercial liquid rennet (Clerici-Sacco Group). Once the pH value reached about 5.2, the curd was cut and mechanically stretched in

hot water, producing Scamorza cheeses of about 200 g each. Cheeses were then stored at 4 ℃ and moved to the experimental ripening room within 30 min.

2.2 Ripening process

The Scamorza samples were divided into two batches: one batch was hung on the lateral carriage (L) and the other one on the central carriage (C) (Figure 1). Both batches were ripened for 7 d in an experimental ripening room which consisted of a thermo stated room containing a dehumidifier which controlled the humidity of the room air[12].

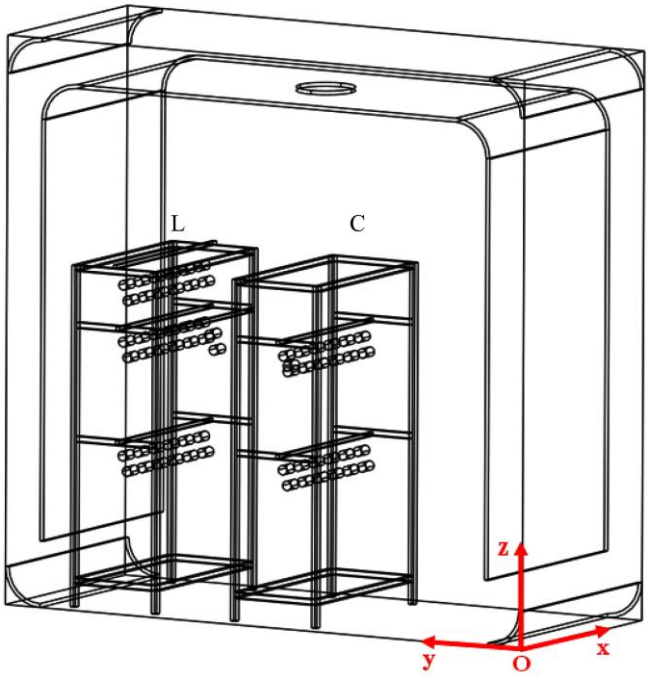


Figure 1 Ripening room simulation and cheeses position: batch L is lateral position and batch C is central position

The ripening tests were carried out with two different sets of temperature and *RH*: (1) T_{min} = 12.0 ℃, T_{max} = 13.0 ℃, RH_{max} = 70%, for 16 h; (2) T_{min} = 9.5 ℃, T_{max} = 11.5 ℃, RH_{max} = 90%, for 6 d. The ripening test was repeated three times.

Scamorza samples were analysed for their physicochemical and microbiological characteristics before ripening (time 0), at 16 h and at 3 and 7 d of ripening.

2.3 Drying system

Experimental tests were carried out on a drying system consisting of a cold room (Figure 2) containing a dehumidifier for the control of the room air humidity. In this system the condensation/drainage stage is omitted since the humid room air is directed out of the ripening room (process air) and the dried air is introduced by the dehumidifier inside the room[12].

The refrigeration system prevents any rise in temperature. In this case, the temperature of the cold battery is maintained at a level above the dew point to avoid vapour condensation and the relative humidity of the room being compromised. In this system the temperature and relative humidity are controlled independently leading to significant benefits. In fact, this system has a positive impact on the amount of electrical energy consumed during the refrigeration process, because less power is required and the system is actively working for a shorter time than a traditional refrigeration system[14].

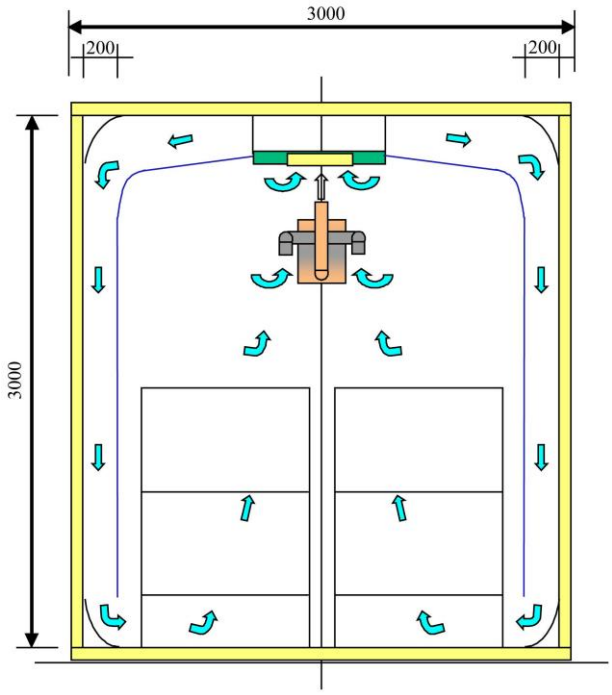


Figure 2 Air circulation in the cell. All dimensions are in mm

2.4 Process parameters

The following process parameters were fixed before starting up the drying system in order to obtain a product of high quality:

1) The daily loss of weight both as a percentage and as the absolute value relative to the intake load of the cold room;

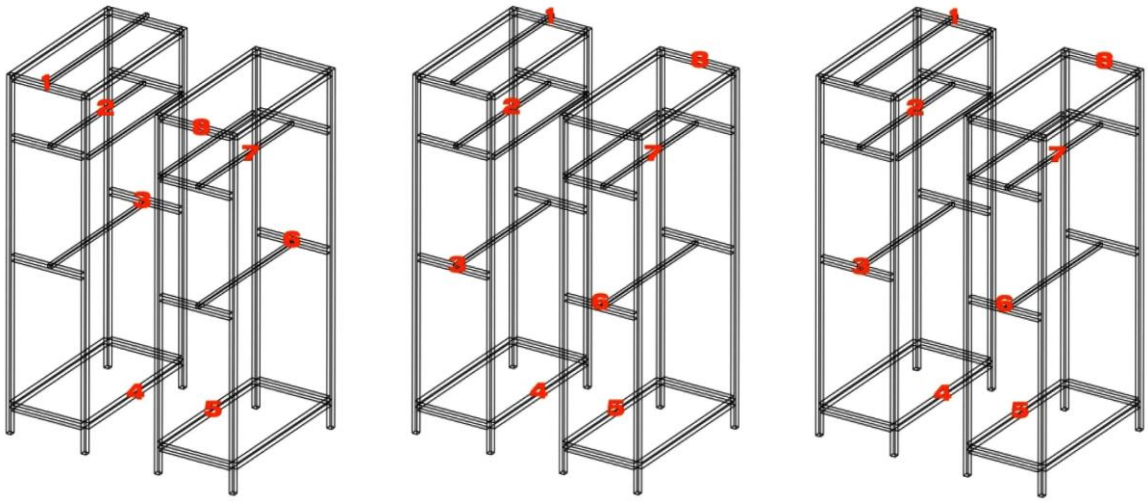
2) The daily dehumidification cycles (a dehumidification cycle is composed of an active period and a pause period of the dehumidifier);

3) The dehumidifier capacity during the pause and process cycles;

4) The length of the dehumidification period which must be planned for each cycle.

In order to monitor the temperatures in the cold room, eight silver plated copper probes (model DLE090 with Pt100 sensing element, LSI Lastem, Milan, Italy) were used. These probes were set at a temperature of 80 ℃. Two HOBO U12-012 probes were also used to measure relative humidity and temperature in the same place. A hot wire anemometer (model BSV101, LSI Lastem) was used to measure the absolute velocity of the air inside the ripening room. Previous probes were connected to a data logger BABUC.

The temperature probes, numbered from 1 to 8, were positioned as shown in Figure 3. The anemometer was placed in the first and second test in the middle of the room, at a height of 115 cm and 23 cm from the floor, respectively; in the third test it was positioned at 50 cm from the lateral panel and 23 cm from the floor. A Hobo sensor was placed on the floor of the room in the middle of the central carriage in the first test, on the central carriage in the second test, and on the floor, in correspondence of the lateral cart, in the third test.



a. First test b. Second test c. Third test

Figure 3 Positions of the temperature probes

2.5 Simulation parameters

The simulation of the ripening room was made by using the COMSOL Multiphysics™ (version 3.5). In the steady-state simulation, attention is focused on both of the fluid dynamic and the thermal conditions of the system when it reaches thermal equilibrium. k-ε model was used for fluid dynamic simulation as it is the most appropriate turbulence model for industrial applications due to a sufficient high Reynolds number and turbulence equilibrium in boundary layers.

Water mass transfer and consequent latent heat were not included since heat transfer from walls is the dominant mechanism at regime (steady-state) operations. Mesh was generated partitioning the domain into approximately 600 000 of tetrahedral mesh elements leading to a degree of freedom (DOF) of over 4 million. To solve the model, a Flexible Generalized Minimum Residual (FGMRES) method was used coupled with a geometric multigrid preconditioner.

In general, heat conductivity is the main material property useful for a steady-state analysis. In our case, the following parameters were set out for the cheese: 1) cheese: thermal conductivity k = 0.37 W/(m Ⱪ); density ρ = 1140 kg/m^3; specific heat (constant pressure) c_p = 3300 J/(kg Ⱪ); starting temperature value T = 288 K air inside cell (standard values at T = 288 K, p = 101.3 kPa where applicable)[15]. 2) ripening room: thermal conductivity k = 0.026 W/(m Ⱪ); density ρ = 1.225 kg/m^3; specific heat (constant pressure) c_p = 1005 J/(kg Ⱪ); dynamics viscosity η = 0.0000179 Pa s; velocity of the air coming out from the evaporator v = 1.5 m/s; starting temperature value T = 288 K; temperature of the air

coming out the evaporator = 283 K.

2.6 Physicochemical analyses

Weight loss of Scamorza cheeses was evaluated on 10 samples of each batch using an electronic balance (AND GF-1200-EC, precision 0.01 g). Water activity (Aw) was determined by a Water Activity Meter CR2 (AQUALAB Instrument, USA), pH was measured by means of a Crison 2001series (Crison Instrument, Spain) and acidity was also determined[16]. The colour of the rind of Scamorza samples was determined using the Hunter L*, a*, b* system with a reflectance spectrophotometer (Minolta CR300b, Japan). The L* variable represents lightness (L*=0 for black, L*=100 for white); a* scale represents the red/green, +a* intensity in red and -a* intensity in green; b* scale represents the yellow/blue, +b* intensity in yellow and -b* intensity in blue. The results were expressed as the mean of three determinations performed on different points of six samples for each batch.

2.7 Structure analyses

Firmness of the cheese was determined on whole samples by measuring the maximum force of compression of a cylindrical probe (P-5 mm diameter) at a speed of 1 mm/s to a depth of 10 mm by means of a Texture Analyser (TA-XT2 Stable Micro Systems, Surrey, England). The thickness of the cheese rind was determined after scanning a cheese slice (2-3 mm thick) and measuring the external layer with a graphic program (Microsoft Photo Editor, 3.0). Three repetitions on each slice were carried out and results were averaged.

2.8 Microbiological analyses

About ten grams of each cheese were aseptically transferred into a sterile stomacher bag, diluted 1:10 with peptone water (Oxoid, Milan, Italy), and homogenised for 2 min in a Lab-blender 400 Stomacher (Seward Laboratory, London, UK). One millilitre of the first dilution was used to obtain tenfold serial dilution for microbial counts. Total mesophilic aerobic bacteria (TMB) were estimated on Plate Count Agar (Oxoid) after 48 h of incubation at 28 ℃. The LAB were counted, under anaerobiosis (AnaeroGen, Oxoid), on de Man, Rogosa, Sharpe (MRS) agar (Oxoid) after 72 h at 22 ℃ for mesophilic LAB and after 48 h at 45 ℃ for thermophilic LAB. *Enterobacteriaceae* were estimated on Violet Red Bile Agar (Oxoid) after 36 h at 37 ℃, total and faecal coliforms on Violet Red Bile Lactose Agar (Oxoid) after 36 h at 37 and 44 ℃, respectively. Yeasts and moulds were quantified on Yeast Extract-Peptone-Dextrose Agar (YPD)[17], after 72 h at 25 ℃.

2.9 Statistical analysis

The analysis of variance (ANOVA) was applied to the data. The least significant differences were obtained using an LSD test ($P < 0.05$). Statistical analysis was performed using an SPSS version 13.0 for Windows (SPSS Inc., Chicago, IL, USA).

3 Results and discussion

As air change rate and temperature are not adequate parameters for characterising the flow field in a cheese ripening room, thermo-fluid-dynamic simulation of the ripening room was carried out in order to compare experimental and numerical values. Some interesting results were seen concerning thermal and fluid dynamics. The model used was, in fact, validated given the slight discrepancy between the experimental results and the simulation data (Table 1).

Table 1 Comparison between the experimental data and simulated data

Section	Hobo - probe	Experimental data	Simulation
1	Hobo	T_d = 11 ℃	T_s = 11 ℃
2	Hobo + probes No. 3-6	T_d = 10 ℃	T_s = 10 ℃
3- Lateral carriage	Probe No. 1	T_d = 10 ℃	T_s = 10 ℃
3- Central carriage	Probe No. 8	T_d = 10.4-10.2 ℃	T_s = 10.7-10.8 ℃

Note: T_d = detected temperature; T_s = simulated temperature.

It highlights that the central zone of the ripening room, when the anemometer was located to a height of 23 cm from the ground, was characterised by a high turbulence (Table 2).

Table 2 Velocity of the airflow inside the ripening room related to the anemometer position

Anemometer position	Mean velocity /m s^{-1}	Standard deviation /m s^{-1}
Cell center (h = 115 cm)	0.07	0.06
Cell center (h = 23 cm)	0.22	0.13
Lateral (d = 50 cm; h = 23 cm)	0.14	0.08
Lateral (d = 5 cm; h = 23 cm)	0.15	0.12

The fluid-dynamic simulation of the ripening room matches with the results obtained by the anemometer

during the experimental tests, highlighting that a turbulence is created in the central part of the ripening room (Figure 4).

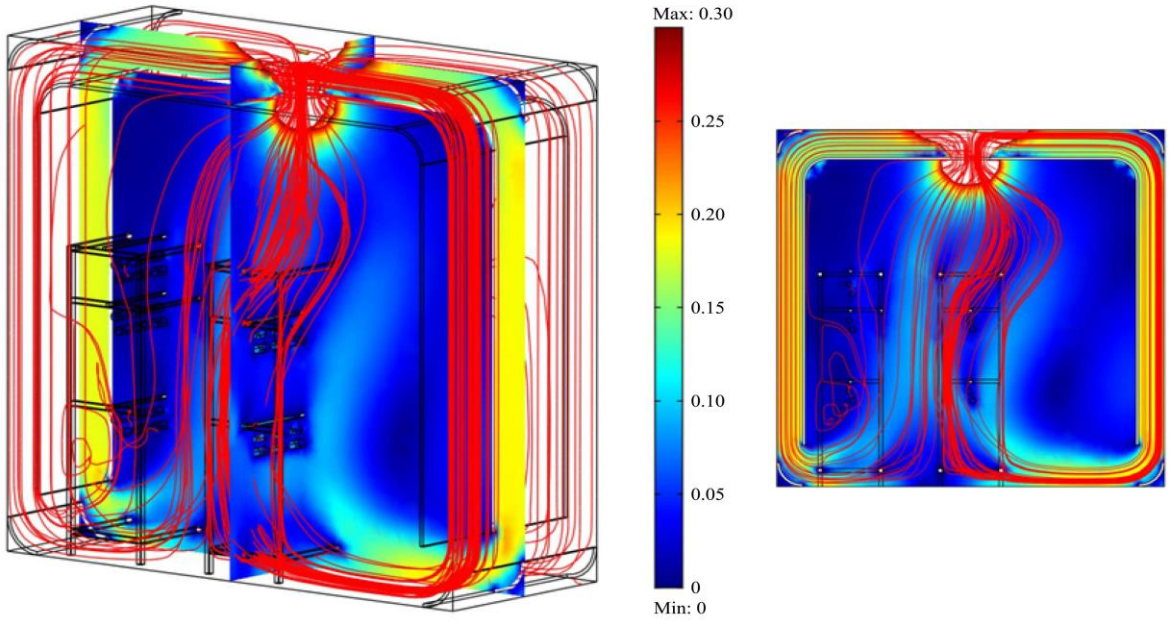


Figure 4 Simulated velocity field (m s^{-1}) of the ripening room

The thermal simulation was carried out taking into account the experimental conditions of the second regulation of the cell: T_{min} = 9.5 ℃ and T_{max} = 11.5 ℃. Also the thermal simulation of the ripening room showed results in accordance with the experimental data logged by the temperature probes and by the Hobo sensors. In the central area higher temperatures were observed (Figure 5).

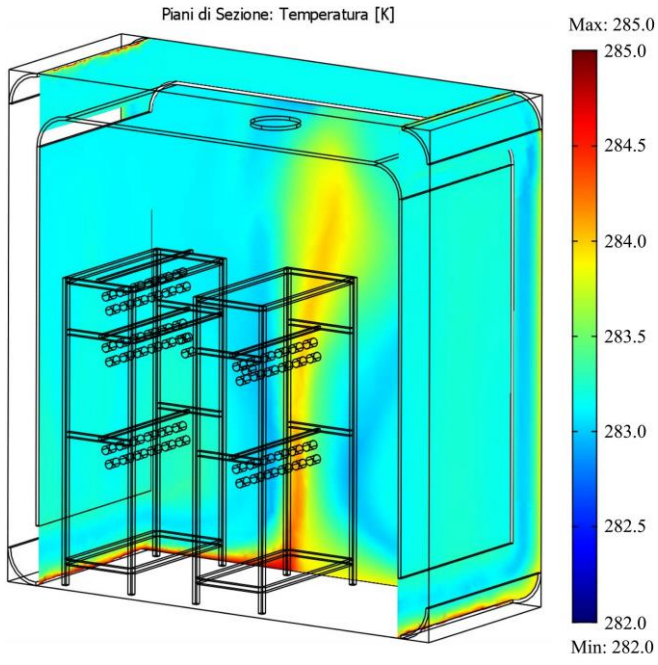


Figure 5 Thermal simulation of the ripening room

Figure 6 shows the weight loss and the water activity trend of the Scamorza cheese samples from batches C and L during the ripening period. With regard to the weight loss, it was possible to observe a decrease in weight in samples from both batches during the ripening period, but with appreciable differences between the two batches (P < 0.05). In fact, samples from the batch C showed a higher weight loss than that of the batch L after 16 h of ripening. The two batches also differed for their water activity values (P < 0.05). This parameter was consistently lower for the batch C samples, although a decrease for both samples was appreciated.

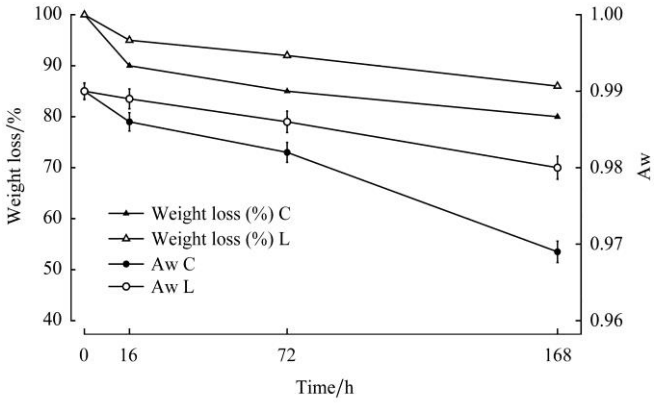


Figure 6 Evolution of weight loss and water activity (Aw) of Scamorza cheeses during the ripening

The results described above highlight that differences of water activity and weight loss between the two batches are due to their location within the ripening room. In particular, in the central zone of the room a higher weight loss of the cheeses was observed with respect to those located on the lateral carriage. This result could be explained by the air turbulence which originates in the central zone (Figure 4). Using simplified models in the numerical analysis, the usefulness of computational thermo-fluid-dynamic for assessing the influence of the position of the product on the performance of ripening room has been clearly shown[12].

During the ripening period, the two batches had a similar rind thickness ($P > 0.05$), which reached values ranging from 1.6 mm to 2.1 mm after 7 d. After 16 h of ripening, samples from batch C showed a higher firmness compared with that of the samples from batch L (0.89 N and 0.63 N of maximum force, respectively). After this period, the values tended to be similar between the two batches (data not shown). The trend of pH and titratable acidity of Scamorza cheeses during the ripening period is reported in Figure 7. Both batches were characterised by a decrease in pH.

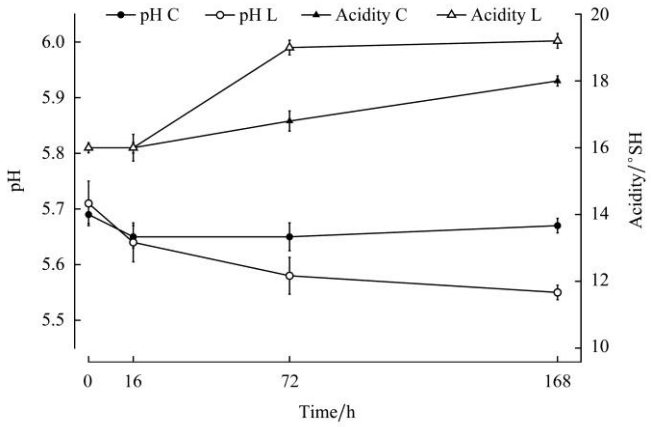


Figure 7 Evolution of acidity (°SH) and pH of Scamorza cheeses during the ripening

In detail, the pH value in samples from the batch C, after a drop during the first 16 h of ripening, remained substantially constant throughout the period of ripening and reached a final value of 5.67. While the pH value in batch L decreased up to the 7th d of ripening, with a final value of 5.5. In general, after the first 16 h of ripening, Scamorza samples from the batch L were characterised by pH levels constantly lower than those appreciated for the batch C. In detail, pH values reached in Scamorza samples from the batch L were consistent with those reported by different Authors[18-22].

As for the determination of titratable acidity, it was possible to appreciate an increase in both batches only after 16 h of ripening. Even in this case, differences were noted between the two batches. In particular, in batch L acidity values were higher than those of batch C.

The rind colour evidenced an increase of the b* index, that is the yellow intensity, during the period of ripening. Moreover, after 7 d of ripening, the yellow index differed significantly ($P < 0.05$) between the two batches. In detail, starting from a b* value of (16.59±0.42) (time 0) the batch L reached a final value (7 d) of (21.93±0.53), higher than that reached in samples from batch C (19.36±0.57). Considering that the yellow intensity of the rind is especially important for its influence on the consumer choice, this datum represents an interesting result. No significant differences in the other indexes (brightness, L* and red index, a*) were found between the two batches under analysis during the ripening (data not shown).

Figure 8 shows the results of the microbiological analyses carried out on Scamorza samples. In both batches, C and L, TMB were characterised by a rapid increase in the first 3 d of ripening and by a subsequent decrease in the final phase. After an initial lag phase, *Eumycetes* (yeasts and moulds) showed an increase since the 3rd d of ripening.

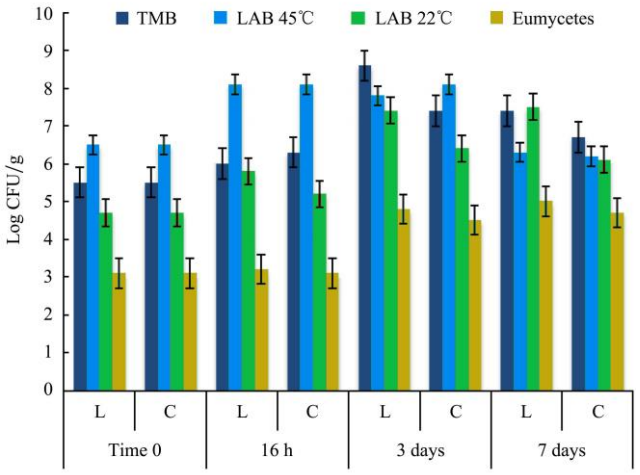


Figure 8 Evolution of microbial populations in Scamorza cheeses during the ripening

All samples showed a high hygienic quality, as evidenced by the very low presence of *Enterobacteriaceae* and total coliforms (< 2.5 log CFU/g), and by undetectable faecal coliforms (< 1 log CFU/g) during the entire ripening period (data not shown).

As for mesophilic LAB, they were present with an initial concentration of about 5 log CFU/g in both batches (Figure 8). In the first 3 d of ripening an increase of mesophilic LAB was observed and this trend remained almost constant until the end of the ripening. However, significant differences between the samples from the two batches ($P < 0.05$) were observed already after 16 h of ripening. In fact, the batch C was characterized by levels of mesophilic LAB constantly lower than those found in the samples from the batch L. In particular, counts registered after 3 d of ripening were 7.4 log CFU/g and 6.4 log CFU/g in batch L and in batch C, respectively. After 7 d, counts in batch L remained almost constant, whereas in batch C a slight decrease was observed. As for thermophilic LAB, high counts were highlighted (about 8 log CFU/g) between 16 h and 3 d of ripening in both batches. However, after this period counts decreased, and after 7 d of ripening recorded counts were 6.3 log CFU/g and 6.2 log CFU/g in batch L and in batch C, respectively.

Results described above could be explained by the higher water activity characterising the Scamorza samples (L) located in the lateral area of the ripening room. This parameter favourably influenced the growth of LAB, whereas the low temperature of ripening advantaged the mesophilic species (i.e. the NSLAB). In our study, the higher counts of NSLAB in samples from the batch L caused a lower pH value and a higher titratable acidity of final products, overall contributing to the definition of typical characteristics of pasta filata cheese, as already stated by different researchers[18-22].

4 Conclusions

The results obtained in this study emphasise the influence of the different zones of the ripening room in the definition of the qualitative characteristics of the Scamorza cheese. Data highlighted a lack of homogeneity in the microclimatic conditions of the ripening room. The more rapid loss of water characterising the samples of the batch C determined an evolution of physicochemical and microbiological features, which resulted different from those of the batch L samples. In particular, this phenomenon determined in the Scamorza cheeses of batch L, placed on the lateral carriage, levels of water activity higher than those of samples placed in the central position, and this fact favourably influenced the behaviour of LAB. So it is possible to assume that the climatic conditions in the lateral area of the ripening room had positive effects on both physicochemical and microbiological characteristics of Scamorza samples from the batch L, also allowed a better definition of yellow pale colour, distinctive for this kind of product.

An important result of the present study is that we clearly highlighted how different levels in ventilation near whole cheeses might influence the weight loss and consequently the quality of the final product. Obviously, further studies are essential to help the industry to correctly design and/or use the ripening rooms. Particular attention should be given to the homogeneity of temperature and of airflow rate around cheeses. The control of these parameters will help operators to carry out correct ripening processes by monitoring the indoor atmosphere of the rooms.

Acknowledgements

Authors wish to thank Caseificio Molisano L. Barone s.n.c. for the production of cheeses. The study was performed within the project “Trasferimento di innovazione nella filiera lattiero-casearia per la valorizzazione del caciocavallo molisano e il recupero di sottoprodotti di trasformazione”, financially supported by PSR Molise 2007-2013 - Misura 124.

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