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Physicochemical and sensory evolutions of the lactic goat cheese Picodon in relation to temperature and relative humidity used throughout ripening

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ABSTRACT

To produce a wide variety of cheeses, it is necessary to control the ripening process. To do that, artisanal goat cheeses were ripened to evaluate the effects of temperature (10 and 14°C) and relative humidity (RH; 88 and 98%) on (1) 16 physicochemical characteristics throughout ripening and (2) 19 sensory characteristics at the end of ripening (d 12). Whatever the ripening time, the physicochemical characteristics were strongly dependent on the daily productions, which affected the sensory perception of the cheeses. Both physicochemical and sensory characteristics were strongly reliant on RH, whereas only a few of the characteristics were influenced by temperature changes. On d 12, whatever the ripening temperature, an RH increase from 88% to 98% modified many cheese characteristics (core pH, lactate consumption, underrind thickening, dry matter content, and hardness). As a result of these physicochemical properties, changes in perception were observed: the cheeses ripened under 88% RH were dry and hard compared with those ripened under 98% RH. An RH of 98% led to an acceleration of the ripening process, inducing a slightly ammonia and milky flavor and a sticky and creamy texture in the mouth. However, cheeses ripened under 14°C and 98% RH were also indicative of overripened cheeses: a temperature of 14°C induced an acceleration of the ripening process due to physicochemical modifications compared with a temperature of 10°C. Nevertheless, when the cheeses on d 0 were still very humid and soft, those ripened under 98% RH collapsed and were overripened with a liquid underrind. This study provides a means for achieving a better and more rational control of the ripening process in artisanal lactic goat cheeses.

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INTRODUCTION

Hundreds of varieties of goat cheese are produced in France (Hassan et al., 2014), with a total of 14 Protected Designation of Origin (**PDO**) cheeses, including Picodon cheese. Their annual production is approximately 22,000 kg, 85% of which are soft, lactic-type cheeses (Bouyssière, 2014). Their sensory qualities such as taste perception, odor, appearance, and texture are dependent on the quality (microbiological and biochemical composition) of the raw milk used to make them; in addition, such qualities are strongly related to the cheese-making process and ripening technologies. Indeed, the latter provide the cheese with its characteristic qualities of taste, smell, appearance, and texture (Choisy et al., 2000). Goat cheeses are produced and ripened on-farm or in small-scale units in which the ripening conditions (e.g., temperature, relative humidity, ventilation) are not well controlled (Raynaud, 2016). However, better control of the cheese-making and ripening processes is necessary to improve the production of these PDO goat cheeses, as previously shown for a Camembert-type cheese by Leclercq-Perlat et al. (2004a,b, 2012, 2015). Consequently, improving lactic goat cheeses by controlling their ripening can have a positive effect on the economic health of small units.

During the first step of ripening that involves cheese drying (d 1–3), lactic goat cheeses are covered with a microflora mainly comprising yeasts (including *Geotrichum candidum*) with some spots of molds, mainly *Penicillium* spp. (Nahabieh and Schmidt, 1990; Gaborit et al., 2001; Raynal-Ljutovac et al., 2011; Raynaud, 2016). As observed in real cheese-making units, the ripening of the cheeses in a ripening room starts after drying and lasts for between 12 and 14 d at temperatures of

10 to 14°C under 80 to 98% relative humidity (**RH**), but these ripening conditions are not controlled. These variabilities can lead to variable qualities of cheeses. Moreover, cheeses might not meet the criteria of PDO Picodon Decree and became unsaleable. Control of cheese quality and of daily production regularity is of utmost importance to allow cheese-makers to offer regular and specific-quality products on the market.

To our knowledge, very few studies have focused on the influence of ripening conditions (temperature and RH) on the physicochemical characteristics and the flavor, taste, appearance, and texture perception of Picodon cheeses. The effects of temperature and RH were studied on proteolysis and lipolysis for goat cheeses by Malcata et al. (1995). These authors showed that an increase in temperature induced more intense effects on these 2 metabolisms than that of RH. Leclercq-Perlat et al. (2012, 2015) and Bonaïti et al. (2004) studied the effects of ripening temperature and RH on the evolution of physicochemical and sensory characteristics throughout the soft cheese ripening process. They highlighted (1) interactions between temperature and RH on microorganism growth, carbon substrate consumption rates, and thickening of the cheese underrind and (2) huge effects on flavor, texture, and appearance perceptions due to microorganism growth and cheese composition changes due to glycolysis, proteolysis, and lipolysis. Other studies (Ramet, 2000; Sihufe et al., 2007, 2010a,b,c; Callon et al., 2011) have reported that temperature plays a predominant role in cheese ripening and that a small increase in temperature accelerates cheese ripening but can also produce off-flavor components in the final product. The influence of texture perception on aroma and taste has been investigated by modification of the product composition or of the process. Pangborn and Szczesniak (1974), Baines and Morris (1987), and Boland et al. (2006) have shown that the interactions between aroma and taste must be taken into account in final perception. Aroma, taste, and texture cross-influences must be investigated using a quantitative descriptive analysis: the sensory profile method (Saint-Eve et al., 2009, 2011). Raynal-Ljutovac et al. (2011) highlighted that the sensorial qualities of French goat cheeses and their effects on consumer acceptance depend on the milk fat, protein, and minerals contents. Gaborit et al. (2001) showed that goat cheeses made with *G. candidum* as a ripening agent were characterized by a strong typical flavor that was related to the lipolytic and flavoring activities of these yeasts. In this context, the aim of this study was to evaluate the effects of temperature and RH on the changes in physicochemical and sensory characteristics throughout the ripening of Picodon cheeses (from d 0 to 12). We hope that this study will provide a means for achieving a better and more rational control of the ripening process of lactic goat cheeses.

MATERIALS AND METHODS

Origin of Lactic Goat Cheeses and Ripening Conditions

Three-day-old Picodon cheeses were obtained from the Station Caprine Expérimentale du Pradel (Mirabel, Ardèche, France), an artisanal French goat farm. These cheeses were produced according to the standard PDO Picodon cheese-making procedure (French Decree, 2000). Briefly, Picodon cheeses were made with milk from the morning milking of goats. When the temperature of this milk was equal to 22 to 23°C, it was seeded with 2% whey from the previous day's cheese production (Dornic acidity from 55 to 65°D). After mixing, the mixture was drawn into 100-L tanks, and then each tank was seeded with 8 mL of rennet (500 mg of chymosin/L). The coagulation lasted 24 h at 20 to 22°C by lactic acid bacteria from the previous day's whey containing mesophilic lactic bacteria (Gaborit et al., 2001). When the Dornic acidity of surnatant whey was higher than 55°D, the curd was carefully poured into mold blocks (diameter: 78 mm; height: 78 mm) of 30 cheeses with a curd shovel without cutting and stirring. The mold draining lasted 24 h, and after 2 h of molding, the molds were turned over. Throughout the draining in molds, the cheeses were salted with a fine solid salt on each side to obtain a final salt level of around 1% on d 12. Forty-eight hours after renneting, the cheeses were turned out. Then, the cheeses were kept in the production room under 22 to 23°C and 90% RH to promote yeast (*Debaryomyces hansenii*, *Kluyveromyces* spp., and sometimes *Yarrowia lipolytica*, but mainly *G. candidum*) development and mold spots (*Penicillium* spp.; Gaborit et al., 2001). Then, the cheeses were dried in a rotary dryer for 48 h under 14 to 16°C and 80% RH. Throughout this drying step, the cheeses were turned over once per day. The cheeses were then ripened in cellars for at least 12 d before wrapping and selling to the consumers, who usually keep them in a refrigerator (2–4°C) before eating them quickly (2–5 d). The end of drying (d 4 of cheese production) was designated as the initial ripening time (d 0). At the end of ripening (d 12), the Picodon cheeses had a cylindrical shape (diameter: 70 mm; height: 18–25 mm). On d 4 (d 0 of ripening), 30 cheeses were weighed and referenced before being placed in the ripening cells (Picque et al.,

2010). Five artisanal daily productions of Picodon goat cheeses were supplied in this way over a 6-mo period.

In this study, the ripening was carried out using a 2-factor, 2-level complete factorial experimental design: temperature (10 and 14°C) and RH (88 and 98%). These 2 levels of ripening conditions were chosen according to the ranges observed during ripening on artisanal lactic goat cheese farms. Whatever the temperature, the ripening runs under 98% RH (designated 10_98 or 14_98) were done in triplicate, whereas the runs under 88% RH (designated 10_88 or 14_88) were done in duplicate. The ripening lasted 12 d. On d 5, the cheeses were weighed and turned over. On d 5 and 12 (end of ripening), 3 cheeses were removed for physicochemical analyses. On d 12, 20 cheeses were sampled for sensory analysis.

Physicochemical Analyses of Lactic Goat Cheeses

Cheese samples were cut in its height (18–25 mm) into 2 halves using a knife. Cheeses were analyzed for rind pH, core pH, underrind and cheese thickness (mm), water activity ($\mathbf{a_w}$), lactate content (g/kg of wet cheese), acid-soluble nitrogen (**ASN**; %), and NPN (%) as previously described by Leclercq-Perlat et al. (1999, 2000, 2004a, 2012). The total fat matter (%) was determined using the AFNOR (1972) method and the lipolytic index (**LI**; mg of KOH/g of wet cheese) as previously described by Mouillet et al. (1981). After pH, texture analyses, and thickness measurements, each Picodon cheese was ground with a Moulinette blender (DPA141, Moulinex, Alençon, France) without separation of the core and the rind.

Texture measurements were adapted from the method, as described by Laithier et al. (2008). Hardness (N) was determined by axial penetration with a stainless steel cylinder (3-mm diameter) in the middle of the half cheese. Cheese samples were tested at a penetration speed of 1 mm/s and a depth of 10 mm. The elasticity and cohesiveness were calculated using the double-bite compression method. This was carried out on 20-mm cheese cubes with an aluminum compression platen (60-mm diameter) with a rest period of 0.09 s between bites. Cheese samples were compressed to a depth of 10 mm with a test speed of 1 mm/s.

For each sampling time, the cheese mass loss (%) and weight loss per day (g/d) were calculated by weighing the cheeses on d 0 and at the end of ripening (Picque et al., 2010). Two criteria commonly used by cheesemakers were also calculated from total fat matter and DM content (%): fat on DM (**FDB**; %) and moisture in nonfat cheese (**MNFS**; %).

Sensory Analysis of Lactic Goat Cheeses on d 12

Twelve panelists (22–55 yr of age; 4 women and 8 men) were recruited to participate in this study according to their motivation and their availability. Sensory analyses were carried out in separate booths under white light. Cheese samples (~25 g) were placed in transparent plastic monocoque boxes (910AEA, Et. Coquard, Villefranche-sur-Saône, France) coded with 3-digit random numbers. They were tempered for 1 h in an air-conditioned room (20 °C) before tasting. Panelists were provided with Evian (Danone, Paris, France) mineral water, a piece of apple, and plain crackers (Cracotte of Lu, Kraft S.A., Vervins, Aisne, France) as palate cleansers between samples. The lactic goat cheeses were evaluated for both aroma and texture perception. To do this, panelists underwent 9 training sessions of 45 min. Throughout these sessions, the panelists first generated attributes based on the differences between cheeses [12-d Picodon cheeses provided by the farm of Pradel (Mirabel, Ardeche, France)]. After a selection step, the panelists worked on the attribute definitions and associated protocols to assess these attributes. The final list of attributes consisted of 19 descriptors: 1 for smell (Sm) to refer to orthonasal olfactory perception, 6 for appearance (Ap), 4 for aroma (Ar) to refer to retronasal olfactory perception when eating, 2 for taste (Ta), and 6 for texture in mouth (Tm; Table 1). The panelists were trained in the proper use of the unstructured linear scales anchored with the terms "very weak" and "very intense." Intensities of attributes were directly recorded on a computer system using FIZZ software (Biosystèmes, 1999). The cheese samples were presented in a monadic way and were distributed using a Latin square design. Within a session, the panelists were asked to use 1 sample to score smell intensity, appearance, and texture to evaluate taste, aroma, and texture in mouth. Throughout each profile session, panelists assessed 4 samples of lactic goat cheeses (2 per ripening condition × 2 cheese replicates). A total of 5 sessions were performed to evaluate 20 lactic goat cheeses.

Statistical Analysis

All statistical tests were performed with XLSTAT-Base software 2016.05 (Addinsoft, Paris, France). All statistical tests with distribution into homogeneous clusters or ranks were carried out with a Bonferroni test at a 99% confidence level.

Reproducibility of Cheese Daily Productions (d 0) and Repeatability of Cheese Sampling. Regardless of ripening time or the physicochemical and

sensory criteria, the normality of these values for 2 runs was not checked at 0.05, even if it was very close to this value (results not shown). Because the normality test was not verified, the repeatability of physicochemical variable medians of the cheese daily production and 3 cheese samples on d 0, 5, and 12 as well as the sensory responses on d 12 were compared using a nonparametric Kruskal-Wallis test. This test makes it possible to determine the χ^2 coefficient, the associated *P*-value, and a distribution of homogeneous ranks. The hypothesis tested was the equality of the median values. The higher the χ^2 coefficient is, the more efficient the factor effect will be. This test was significant if the *P*-value was lower than the risk α [$\alpha = 1 - p(\chi^2_{obs} < \chi^2_{crit})$], where p is the probability value, χ^2_{obs} is the value of χ^2 calculated by XLSTAT, and χ^2_{crit} is the theoretical value obtained from the tables (Cohen, 1992).

Effects of Cheese Daily Production, Temperature, RH, and Panelist Responses. To determine the effects of temperature and RH on d 5 and 12, a 3-way ANOVA (cheese daily production, temperature, and RH) and a 4-way ANOVA (panelist, cheesemaking, temperature, and RH) were performed on physicochemical variables and on sensory descriptors, respectively. These ANOVA were carried out with orthogonal decomposition of least squares with the Fisher coefficient and *P*-value comparisons and with distribution into homogeneous clusters. The hypothesis was the existence of a mean value of temperature × RH run different from the 1 of the 3 other ripening condition runs. The higher the Fisher coefficient is, the more efficient the factor effect will be, and this test was significant if the *P*-value was lower than the risk α.

To highlight the interaction factor (temperature × RH) on the physicochemical and sensory criteria, an analysis of the differences between 2 ripening condition runs was used with the cross-interaction factor of a 2-way ANOVA (temperature and RH) with distribution into homogeneous clusters (Cohen, 1988). The hypothesis tested was the equality of these differences of six 2 × 2 comparisons with a critical value (t, Student coefficient). If this 2 × 2 difference was higher than t, the hypothesis of equality was rejected. Whatever the statistical test and its hypotheses, if the risk $\alpha = 0.05$, the test was slightly significant; if $\alpha = 0.01$, it was significant, and if $\alpha = 0.001$, it was very significant.

Relationships Between Sensory and Physicochemical Criteria on d 12. To check the relationships between these 2 sets of data, the correlation matrix of Pearson was established with a 99% confidence level. To go further and to visualize the correlations existing between variables, a principal component analysis (**PCA**) of median values in a 2-dimension plan was carried out. Nineteen sensory descriptors were chosen as active variables because they described the cheeses consumed by people, and 16 physicochemical variables were defined as supplementary ones to explain them. To classify the products on PCA, a hierarchical classical

Table 1. List of sensory descriptors generated and selected by consensus of 12 panelists, their notation, and the meaning of scale limits

Sensory property	Sensory descriptor	Notation[1]	Scale limits 0	Scale limits 10
Smell	Ammonia	Sm_NH_3	Not detected	Very intense
Appearance	Rind thickness	Ap_Rind thickness	Thin	Thick
	Underrind thickness	Ap_Underrind thickness	Absent	Full
	Rind hardness	Ap_Rind hardness	Soft	Hard
	Wrinkled rind	Ap_Wrinkled rind	Smooth	Very wrinkled
	Stained rind	Ap_Stained rind	No spot	Many spots
	Differences between top and bottom sides	Ap_≠ top/bottom	Not difference	Many differences
Aroma	Goat	Ar_Goaty	Not detected	Very intense
	Fruity	Ar_Fruity	Not detected	Very intense
	Pungent	Ar_Pungent	Not detected	Very intense
	Milky	Ar_Milky	Not detected	Very intense
Taste	Bitter	Ta_Bitter	Not detected	Very intense
	Salty	Ta_Salty	Not detected	Very intense
Texture in mouth	Creamy	Tm_Creamy	Not creamy	Very creamy
	Sticky	Tm_Sticky	Not sticky	Very sticky
	Hardness	Tm_Hardness	Soft	Hard
	Grainy	Tm_Grainy	Smooth and homogeneous	Grainy and heterogeneous
	Moisture	Tm_Moisture	Dry	Moist
	Pasty	Tm_Pasty	Runny	Pasty and slimy

[1]Sm = smell; Ap = appearance; Ar = aroma; Ta = taste; Tm = texture in mouth.

analysis on products from physicochemical and sensory variables was performed based on Ward distance.

A variable was significant if the correlation coefficient or the absolute value of its cosine on 1 of 2 axes was higher than 0.70. To identify the group of homogeneous or atypical observations in this 2-dimensional plan, a PCA between individual runs was carried out.

RESULTS AND DISCUSSION

Reproducibility of Cheese Daily Productions (d 0) and Repeatability of Cheese Sampling

On d 0, the reproducibility of all physicochemical variables was studied in relation to the cheese daily productions. A significant variability between cheese daily productions was observed. Indeed, physicochemical results showed unsatisfactory hypotheses of equality, except for a_w, elasticity, and cohesiveness with $\alpha = 0.05$ (results of the Kruskal-Wallis test not shown). For the 13 other variables, the 5 daily productions of cheese could be classified in relation to hardness and DM of d 0 cheese.

The first group of productions comprised 2 productions characterized by the cheeses with the highest hardness (2.6 ± 0.3 N) and DM (51.5 ± 0.7%). The second group consisted of 1 other production described as the softest (hardness = 1.0 ± 0.1 N) and the wettest (DM = 39 ± 2%) cheeses. The last group was formed by the 2 last productions whose cheeses were soft (hardness = 1.3 ± 0.1 N) and wet (DM = 42.7 ± 1.6%). Moreover, the other physicochemical variables of this last cheese production were intermediate to those of the 2 other sets of productions.

For the same ripening run, whatever the ripening time, no significant differences in physicochemical and sensory properties were found between the 3 cheeses sampled (results not shown). Indeed, the hypotheses of equality were verified with a confidence level of 99%. This allowed us to test the influence of ripening conditions on the 16 physicochemical and 19 sensory criteria taking the cheese daily production effect alone into account.

In conclusion, there was a very significant daily production effect, which is usually the case in artisanal processes. Indeed, the composition of goat milk affects the physicochemical characteristics, which can affect the acceptability of these ripened cheeses (Raynal-Ljutovac et al., 2011; Hassan et al., 2014). The technological, physicochemical, and sensory characteristics of goat cheeses have been shown to be related to the composition and quality of the goat diet (Alvarez et al., 2007; Raynal-Ljutovac et al., 2011; Gomes de Oliveira et al., 2012; Santos et al., 2016). Moreover, the lactic goat cheese ecosystem (Nahabieh and Schmidt, 1990; Gaborit et al., 2001) varies in terms of composition and enzymatic activities depending on the goats' diet or seasonal variations and the milk seeding method (using the lactoserum produced throughout the previous cheese-making; French Decree, 2000). According to Raynaud (2016), Picodon cheese-making (e.g., milk seeding, acidification, molding) and ripening practices are still very empirical and vary greatly from one farm to another. However, within the same cheese daily production, all of the cheeses were statistically comparable. This showed the repeatability of daily production for the same parameters (e.g., milk, environmental conditions, drying conditions).

Influence of Temperature and RH on Physicochemical Descriptors

Tables 2A and B give the statistical results of the 3-way ANOVA (daily production, temperature, and RH) on the 16 physicochemical variables on d 5 and 12, respectively. Whatever the ripening time, the cheese production factor had a very significant effect ($P < 0.001$) on 14 of 16 physicochemical variables, whereas it had only a slight effect on cheese mass loss and no effect on weight loss per day.

On d 5, temperature had no significant effect on 9 of 16 physicochemical variables, whereas a slight effect on weight loss per day, a significant effect on cheese mass loss, and a huge influence on the 5 other physicochemical variables (rind pH, ASN, lipolytic index, lactate content, and underrind thickness) were observed with a 99% confidential level (Table 2A). An increase in temperature from 10 to 14°C led to an increase in rind pH, ASN, lipolytic index, and underrind thickness, whereas it decreased the influence on lactate content and cheese mass loss (Table 2A). Relative humidity had a strongly significant effect on 12 of 16 variables. A change in RH from 88 to 98% led to an increase in 7 variables (rind pH, FDB, MNFS, ASN, NPN, underrind thickness, and cohesiveness) and a decrease in 5 other variables (DM, hardness, lactate content, weight loss per day, and cheese mass loss).

On d 12, temperature had a significant effect on a_w and a huge effect on the 7 other criteria (Table 2B). An increase in temperature from 10 to 14°C led to an increase in core pH, DM, ASN, and underrind thickness, whereas it led to a decrease in FDB, MNFS, lactate content, and a_w. Relative humidity had a huge effect on 12 of 16 variables and a significant effect on a_w. A

change in RH from 88 to 98% positively affected core pH, FDB, MNFS, ASN, NPN, lipolytic index, a_w, and underrind thickness and negatively affected DM, hardness, lactate content, weight loss per day, and cheese mass loss criteria.

On the basis of these ANOVA, no cross-effect between temperature and RH was observed (results not shown). These interactions can be hidden by the major variations of physicochemical variables in the cheeses from one daily production to another, as observed on d 0. However, cheeses ripened at 14°C under 98% RH were different from those ripened under the 3 other conditions for all physicochemical parameters. In fact, effects due to 98% RH were accentuated when the cheeses were ripened at 14°C. For example, on d 12, under 98% RH, the creamy underrind of cheeses ripened at 14°C became more runny than that of the cheeses ripened at 10°C on d 5. Moreover, the cheeses ripened under 14°C and 98% RH sagged, losing their cylindrical shape. This was due to the huge decrease in cheese thickness (around 35%) and an important increase in their diameter (around 40%), as also shown by Raynaud et al. (2016). Moreover, Bonaïti et al. (2004) and Leclercq-Perlat et al. (2012, 2015) also showed the importance of ripening condition interactions on the creamy underrind thickness and its consistency.

Table 2. Statistical results of the 3-way ANOVA (cheese daily production, temperature, and relative humidity) on physicochemical variables on d 5 and 12

	Cheese production	Temperature			Relative humidity		
Item[1]	F[2]	F	10°C	14°C	F	88%	98%
d 5							
Δwt/d	2	5*	1.3[a]	1.5[a]	264***	2.0[b]	1.0[a]
ΔMass	3*	9**	8.0[b]	7.4[a]	179***	10.9[b]	5.5[a]
DM	183***	3	49.1[a]	49.7[a]	18***	52.3[b]	47.5[a]
FDB	11***	1	49.0[a]	45.7[a]	15***	45.3[a]	48.6[b]
MNFS	35***	3	66.9[a]	64.9[a]	16***	62.3[a]	68.2[b]
H	97***	0	2.0[a]	1.9[a]	31***	2.3[b]	1.6[a]
El	14***	0	1.5[a]	1.5[a]	0	1.5[a]	1.6[a]
Co	15***	0	3.1[a]	3.3[a]	28***	3.0[a]	3.4[b]
a_w	76***	1	0.978[a]	0.978[a]	1	0.978[a]	0.979[a]
pH_{rind}	19***	24***	7.2[a]	7.4[b]	9***	7.2[a]	7.4[b]
pH_{core}	30***	1	4.5[a]	4.5[a]	2	4.5[a]	4.5[a]
ASN	109***	115***	21.5[a]	24.0[b]	14***	18.8[a]	25.4[b]
NPN	49***	2	12.8[a]	9.8[a]	15***	10.0[a]	12.2[b]
LI	45***	30***	9.8[a]	13.0[b]	1	10.5[a]	12.1[a]
LA	91***	33***	9.8[b]	8.9[a]	17***	9.8[b]	9.0[a]
T_{UR}	162***	38***	14.6[a]	25.6[b]	64***	12.7[a]	21.7[b]
d 12							
Δwt/d	1	0	1.3[a]	1.4[a]	102***	2.0[b]	0.9[a]
ΔMass	6*	0	16.6[a]	17.6[a]	179***	26.3[b]	11.0[a]
DM	359***	26***	54.0[a]	55.6[b]	177***	60.7[b]	50.9[a]
FDB	11***	11***	44.9[b]	41.0[a]	152***	39.2[a]	45.4[b]
MNFS	243***	28***	60.3[b]	57.0[a]	167***	51.2[a]	63.6[b]
H	100***	5	2.9[a]	2.6[a]	66***	4.4[b]	1.9[a]
El	8***	0	1.3[a]	1.4[a]	1	1.3[a]	1.4[a]
Co	6***	5	3.2[a]	3.4[a]	1	3.5[a]	3.2[a]
a_w	11***	11**	0.974[b]	0.971[a]	12**	0.969[a]	0.978[b]
pH_{rind}	190***	3	7.6[a]	7.6[a]	0	7.4[a]	7.7[a]
pH_{core}	90***	14***	4.6[a]	4.8[b]	38***	4.5[a]	4.8[b]
ASN	110***	15***	30.0[a]	33.5[b]	61***	25.5[a]	36.1[b]
NPN	63***	5	14.8[a]	14.9[a]	91***	11.9[a]	16.5[b]
LI	108***	0	13.8[a]	16.6[a]	18***	12.7[a]	12.1[b]
LA	105***	72***	6.6[b]	4.3[a]	94***	7.5[b]	4.0[a]
T_{UR}	151***	215***	21.2[a]	39.2[b]	345***	19.5[a]	37.5[b]

[a,b]Within a variable (temperature or relative humidity), values within a row with the same letter are in statistically homogeneous groups based on the Bonferroni test with a 99% confidence level.[1]Δwt/d = weight loss (g) per day; Δmass = cheese mass loss (%); DM = DM content (g of dry cheese/100 g of wet cheese); FDB = fat on a dry basis (%); MNFS = moisture in nonfat solids (%); H = hardness (N); El = elasticity; Co = cohesiveness; a_w = water activity; ASN = acid-soluble nitrogen (%); NPN = NPN (%); LI = lipolytic index (mg of KOH/g); LA = lactate content (g/kg of wet cheese); T_{UR} = thickness of underrind (%).

[2]F = Fisher coefficient.

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Indeed, when all the cheese-making protocol steps were correctly standardized (Leclercq-Perlat et al., 2004a, 2012), these interactions played a leading role in the soft cheese ripening process.

To highlight the existence or not of this cross-interaction (temperature × RH), analyses of 2 × 2 ripening condition differences were carried out. This made it possible to show that there was a very significant effect on the 16 physicochemical variables between cheeses ripened at 14°C under 98% RH compared with the 3 other ripening conditions (results not shown). Indeed, whatever the ripening time, an increase in temperature from 10 to 14°C had a huge influence on cheeses ripened under 98% RH, whereas it did not affect the cheeses ripened under 88% RH. An increase in RH from 88 to 98% had an effect on cheeses ripened at 14°C but did not significantly affect the ones ripened at 10°C. This could explain the strong cross-effect observed under 98% RH and 14°C. Whatever the ripening time, a very strong effect of the factor daily production had been highlighted on the studied physicochemical variables (Table 2). Despite this, on d 5, the influences of temperature and RH were clearly shown for 6 and 12 of the 16 physicochemical variables, respectively. Considering the Fisher coefficient value, temperature influenced only LI and affected it more significantly than RH for only 3 descriptors linked to microflora metabolism: rind pH, ASN, and lactate content. In contrast, it had less influence than RH on cheese mass loss and underrind thickness. Relative humidity strongly affected the physicochemical variables linked to cheese DM content (DM, cheese mass loss, weight loss per day, FDB, MNFS, hardness, cohesiveness, and underrind thickness). Except for NPN, when there was an effect of temperature, the influence of RH was less than that of temperature for physicochemical variables linked to microorganism metabolisms. On d 12, contrary to the results of Callon et al. (2011) and Sihufe et al. (2007, 2010a,b,c) obtained for other types of cheeses (pressed uncooked cheeses or Reggianito Argentino cheese), temperature and RH effects were not observed on the 3 physicochemical variables (elasticity, cohesiveness, and rind pH). Temperature and RH played a leading role in lactic goat cheese ripening for 8 and 13 physicochemical variables, respectively. For a_w, temperature and RH had approximately the same effect. For the other temperature-dependent variables, the influence of RH was more important than that of temperature (DM, FDB, MNFS, core pH, ASN, lactate content, and underrind thickness). This could be explained by the measurement range used for RH (88–98%) compared with that used for temperature (10–14°C). Indeed, for a Camembert-type cheese, Leclercq-Perlat et al. (2012) found significant effects for these 2 ripening conditions on physicochemical variables when the measurement ranges were 8 to 16°C for temperature and 88 to 98% for RH. The influence of temperature and RH was observed only for lactic goat cheeses ripened under 98% RH and 14°C compared with the 3 other conditions. This could be explained by the variations in daily production parameters as well as by the measurement range used for temperature. Indeed, Leclercq-Perlat et al. (2012) pointed out that the interactions between temperature and RH played a major role in microorganism growth, carbon substrate consumption, nitrogen fraction evolution, lipolysis evolution, and the thickening of the cheese underrind. On d 5 or 12, the comparison of lactic goat cheeses ripened at 14°C with those ripened at 10°C made it possible to conclude that an increase in temperature affected physicochemical variables related to enzymatic activities due to the surface microflora: pH, ASN, LI, and lactate. This may explain the observed creamy underrind thickness variations (~8% thicker at 14°C than at 10°C under 98% RH). These results are in agreement with those of Leclercq-Perlat et al. (2004a, 2012) and Malcata et al. (1995).

Throughout ripening runs under 88% RH, lactic goat cheeses lost twice as much water (cheese mass loss and weight loss per day) on d 5 and approximately 2.3 times more on d 12. Consequently, they were the driest (DM = 4.8% more on d 5 and 9.8% more on d 12) and hardest (hardness = 0.7 N more on d 5 and 2.5 N more on d 12) compared with those ripened under 98% RH. These physicochemical variables are strongly related to the atmospheric conditions in the ripening rooms and especially to RH (Picque et al., 2010). Moreover, a_w is correlated with RH (Hardy, 1997; Hardy et al., 2000). Cheeses ripened under 88% RH exhibited an a_w (0.969) lower than those refined under 98% RH (0.978). These authors highlighted that no limitation of ripening microorganism growth is observed when a_w is close to 0.980.

Influence of Temperature and RH Changes on Sensory Perception

As expected in sensory profile analyses, a huge significant panelist effect was observed for all sensory attributes (Table 3), suggesting differences in sensibility between panelists. Moreover, significant differences induced by daily production, temperature, RH, and the temperature × RH cross-interaction were obtained for sensory attributes. Indeed, daily production effect significantly affected the perception of 17 out of 19 sensory attributes, but it did not affect the perception of appearance differences between the top and bottom

Table 3. Statistical results of the 4-way ANOVA (panelists, cheese daily production, temperature, and relative humidity) as well as the interaction between temperature and relative humidity on sensory descriptors on d 12

	Panelist	Daily production	Temperature (T)			Relative humidity (RH)			T × RH
Sensory attribute[1]	F[2]	F	F	10°C	14°C	F	88%	98%	F
Sm_NH_3	27***	6***	1	2.7[a]	2.9[a]	2	2.6[a]	3.0[a]	0
Ap_Rind thickness	35***	7***	4	1.8[a]	2.0[a]	18***	1.5[a]	2.3[b]	2
Ap_Underrind thickness	34***	38***	1	2.3[a]	2.4[a]	30***	2.0[a]	2.7[b]	4
Ap_Rind hardness	29***	28***	2	4.1[a]	3.9[a]	89***	5.0[b]	3.0[a]	7**
Ap_Wrinkled rind	26***	22***	5*	4.0[a]	4.4[a]	0	4.3[a]	4.2[a]	1
Ap_Stained rind	18***	4**	1	1.3[a]	1.2[a]	0	1.2[a]	1.2[a]	0
Ap_≠ top/bottom	14***	1	0	1.7[a]	1.7[a]	6*	1.9[a]	1.5[a]	0
Ar_Goaty	19***	7***	0	4.0[a]	4.1[a]	1	4.2[a]	4.0[a]	2
Ar_Fruity	37***	6***	1	2.5[a]	2.7[a]	12***	2.9[b]	2.3[a]	0
Ar_Pungent	47***	12***	1	1.6[a]	1.4[a]	0	1.4[a]	1.5[a]	0
Ar_Milky	45***	6***	1	3.5[a]	3.5[a]	47***	2.8[a]	4.2[b]	2
Ta_Bitter	20***	4**	0	2.6[a]	2.8[a]	2	2.6[a]	2.9[a]	1
Ta_Salty	22***	4**	1	2.6[a]	2.7[a]	0	2.8[a]	2.6[a]	0
Tm_Creamy	23***	33***	2	3.5[a]	3.1[a]	73***	2.2[a]	4.3[b]	5*
Tm_Sticky	51***	9***	0	4.5[a]	4.4[a]	0	4.3[a]	4.5[a]	1
Tm_Hardness	24***	32***	1	3.5[a]	3.8[a]	68***	4.5[b]	2.7[a]	5*
Tm_Grainy	27***	2	1	2.3[a]	2.6[a]	18***	2.9[b]	2.0[a]	4*
Tm_Moisture	40***	59***	0	4.2[a]	4.1[a]	107***	3.1[a]	5.2[b]	5*
Tm_Pasty	39***	3*	1	4.8[a]	5.0[a]	10**	5.3[b]	4.5[a]	0

[a,b]Within a variable (temperature or relative humidity), values within a row with the same letter are in statistically homogeneous groups based on the Bonferroni test with a 99% confidence level.[1]Sm = smell; Ap = appearance; Ar = aroma; Ta = taste; Tm = texture in mouth.

[2]F = Fisher coefficient.

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

sides or that of grainy texture in the mouth (Table 3). Temperature had a slight effect on the perception of wrinkled rind appearance. Relative humidity significantly affected 10 out of 19 sensory attributes. An increase in RH from 88 to 98% led to an increase in rind thickness and underrind thickness appearance, milky aroma, and a creamy and moist texture in the mouth, whereas it led to a decrease in 5 other perception attributes: rind hardness texture, fruity aroma, and hardness and grainy and pasty texture in the mouth. No cross-effect between temperature and RH was observed for the majority of perception attributes. Only rind hardness appearance was significantly linked to the temperature × RH cross-interaction, whereas 4 of 6 texture-in-mouth perception attributes (creamy, hardness, grainy, and moisture) were only slightly significantly related to this cross-interaction. However, the analyses of 2 × 2 ripening condition differences made it possible to show that there was a highly significant effect on the 19 perception attributes between cheeses ripened at 14°C under 98% RH compared with the 3 other ripening conditions (results not shown).

Despite this significant "daily production" effect (Table 3), RH strongly influenced lactic goat cheese perception (10 of 19 sensory attributes). However, no significant temperature effects on these attributes could be observed. Temperature effects could be hidden by the cheese daily production effect due to the range of 10 to 14°C studied, which was relatively limited. On d 12, throughout all of the ripening runs under 88% RH, lactic goat cheeses were significantly harder (1.8 more for Ap_Rind hardness), more granular (0.9 more for Tm_Grainy), and more pasty (0.8 times more for Tm_Pasty) and their rinds were harder (2 more for Ap_Rind hardness) than those ripened under 98% RH. This can be explained by the high water evaporation from the cheese surface. This evaporation causes the rind to dry and water to diffuse from the core, leading to cheese drying. This decrease in water leads to limitations of microorganism growth and of microbial enzymatic activities for ripening under 88% RH (Ramet, 2000; Bonaïti et al., 2004; Leclercq-Perlat et al., 2015). In contrast, cheeses ripened under 98% RH had a thicker rind (0.8 more), a moister texture in the mouth (2.1 more), and a thicker (0.7 more) and creamier (2.1 more; more runny) underrind than cheeses ripened under 88% RH. These perceptions could be linked to ripening microorganism growth, pH, carbon substrate metabolism, cheese moisture, and microbial enzymatic activities (Gaborit et al., 2001). Indeed, these authors have pointed out that (1) *G. candidum* as a ripening agent led to the development of a suitable typical flavor and satisfying overall sensorial characteristics and (2) the development of a suitable typical flavor requires a certain level of lipolysis that should be controlled to limit the occurrence of flavor flaws.

Indeed, creamy texture in the mouth is related to underrind consistency. The underrind thickness appearance is linked to proteolysis and lipolysis evolutions. These attributes are overall scores of enzymatic activity markers that take place near the cheese rind. Moreover, the phenomenon of water evaporation from the cheese surface to the atmosphere and the water diffusion from the core can be explained by the 98% RH effects observed on rind thickness appearance and moisture in the mouth. Indeed, the water transfers that take place in soft cheeses do not inhibit ripening microorganism growth, except for *Penicillium* spp. (Lenoir et al., 1985; Lesage-Meessen and Cahagnier, 1998), or their microbial enzymatic activities (Choisy et al., 2000; Ramet, 2000). The fruity aroma was perceived by the panelists as being significantly stronger for cheeses ripened under 88% RH, whereas the milky aroma was more for cheeses ripened under 98% RH. This could be explained by differences in composition and growth of the ripening flora (Nahabieh and Schmidt, 1990; Gaborit et al., 2001). Indeed, some yeasts (*D. hansenii* or *Kluyveromyces* spp.) are known to produce fruity aromas (Leclercq-Perlat at al., 2004b), whereas *G. candidum* contributes the milky, cheesy, sweaty, slight fruity, yeasty, and musty aromas of soft cheeses (Gaborit et al., 2001). Even though *G. candidum* can induce a decrease in diacetyl production (Boutrou and Guéguen, 2005), the main compound of milky flavor, this compound is water soluble (Saint-Eve et al., 2006) and can therefore be better perceived by the panelists in the wettest cheeses ripened under 98% RH.

Even if a significant temperature effect could not be highlighted, this effect coupled with the highly significant RH effect can be seen on 6 descriptors. This is in agreement with the studies of Bonaïti et al. (2004), Choisy et al. (2000), and Leclercq-Perlat et al. (2015).

Relationships Between Perception and Physicochemical Variables on d 12

Table 4 shows the part of the correlation matrix established between perception attributes and physicochemical variables on d 12 with a 99% confidence level. Only correlation coefficients higher than 0.70 are significant. No significant relationships were found between 4 perception attributes (wrinkled rind appearance, fruity and milky aroma, and pasty texture in the mouth) and physicochemical variables. Three physicochemical variables (a_w, rind pH, and elasticity) were not linked to any perception attributes.

Concerning perception appearance, rind thickness was positively linked to core pH, ASN, lipolytic index, and underrind thickness (%) and negatively linked to hardness and lactate content, whereas the underrind thickness was linked positively only to core pH and underrind thickness (%) and negatively to lactate content. Rind hardness was favorably linked to cheese mass loss, DM, hardness, and lactate content but negatively linked to MNFS, core pH, ASN, NPN, and underrind thickness (%). Stained rind was positively related to hardness and negatively correlated with core pH and

Table 4. Correlation matrix established between sensory descriptors and physicochemical variables according to a Pearson correlation matrix test with a 99% confidence level

	Physicochemical variable[2]												
Sensory descriptor[1]	Δwt/d	ΔMass	DM	FDB	MNFS	H	Co	pH_{core}	ASN	NPN	LI	LA	T_{UR}
Sm_NH_3	—	—	—	—	—	—	—	0.77	—	—	—	−0.84	—
Ap_Rind thickness	—	—	—	—	—	−0.73	—	0.87	0.73	—	0.86	−0.88	0.79
Ap_Underrind thickness	—	—	—	—	—	—	—	0.89	—	—	—	−0.95	0.84
Ap_Rind hardness	—	0.74	0.88	—	−0.77	0.83	—	−0.83	−0.76	−0.75	—	0.96	−0.84
Ap_Stained rind	—	—	—	—	—	0.81	—	−0.78	—	—	−0.85	—	—
Ap_≠ top/bottom	—	—	—	—	—	0.77	0.82	—	—	—	—	—	—
Ar_Goaty	—	—	—	—	—	—	—	—	—	—	—	−0.79	—
Ar_Pungent	—	—	—	—	—	—	—	0.73	—	—	—	−0.81	—
Ta_Bitter	—	—	—	—	—	—	—	0.72	—	—	—	−0.77	—
Ta_Salty	—	—	—	—	—	—	—	—	—	—	—	−0.75	—
Tm_Creamy	—	−0.79	−0.75	—	0.79	−0.74	—	0.88	0.75	—	0.74	−0.92	0.85
Tm_Sticky	—	−0.72	−0.74	—	0.73	−0.78	−0.73	—	0.80	—	—	−0.74	—
Tm_Hardness	—	0.74	0.88	—	−0.85	0.81	—	−0.77	−0.84	−0.81	−0.73	0.96	−0.82
Tm_Grainy	0.89	0.77	—	−0.76	—	—	—	—	—	—	—	—	—
Tm_Moisture	—	—	−0.77	—	0.72	−0.76	—	0.88	0.79	—	0.72	−0.96	0.87

[1]Sm = smell; Ap = appearance; Ar = aroma; Ta = taste; Tm = texture in mouth.

[2]Δwt/d = weight loss (g) per day; Δmass = cheese mass loss (%); DM = DM content (g of dry cheese/100 g of wet cheese); FDB = fat on a dry basis (%); MNFS = moisture in nonfat solids (%); H = hardness (N); Co = cohesiveness; ASN = acid-soluble nitrogen (%); NPN = NPN (%); LI = lipolytic index (mg of KOH/g); LA = lactate content (g/kg of wet cheese); T_{UR} = thickness of underrind (%).

lipolytic index, whereas top/bottom difference was linked only to hardness and cohesiveness.

Concerning texture in the mouth, the creamy perception was positively related to MNFS, core pH, ASN, lipolytic index, and underrind thickness (%) and negatively related to cheese mass losses, DM, hardness, and lactate content. The sticky sense was positively linked to MNFS and ASN but negatively linked to cheese mass losses, DM, hardness, cohesiveness, and lactate content. Hardness in the mouth was positively linked to cheese mass loss, DM, hardness, and lactate content and negatively linked to MNFS, core pH, ASN, NPN, lipolytic index, and underrind thickness (%) measurements. Grainy perception was favorably linked to weight loss per day and cheese mass loss and negatively linked to MNFS. Moisture was positively correlated with MNFS, core pH, ASN, lipolytic index, and underrind thickness (%) but negatively correlated with DM, hardness, and lactate content.

Principal component analyses made it possible to visualize the relationships between the perception descriptors and physicochemical measurements as well as the ripening condition influences. Principal component analysis was carried out on the 19 sensorial descriptors as active variables and the 16 physicochemical variables as supplementary variables. The first 2 principal components explained 74% of the total variance, with 57% for factor axis 1 and 17% for factor axis 2 (Figure 1).

The physicochemical variables (lactate content, hardness, and DM) and the perception attributes (Ap_Rind hardness, Ap_Stained rind, Tm_Hardness) typical of the lowest ripening conditions were negatively correlated with factor axis 1, whereas the physicochemical criteria (core pH, underrind thickness, ASN, and lipolytic index) and those of perception (Tm_Moisture, Ap_Underrind thickness, Tm_Creamy, Sm_NH_3, Ar_Pungent, Ap_Rind thickness, Ta_Salty, Ta_Bitter, Ar_Goaty, and Tm_Sticky) related to ripening conditions were positively associated with factor axis 1. A physicochemical variable (FDB) and 2 perception attributes (Ar_Milky and Tm_Pasty) were positively related to factor axis 2, whereas only grainy texture in the mouth was negatively linked to factor axis 2 (Figure 1).

Changes in physicochemical cheese composition induced by microorganism metabolism (Dugat-Bony et al., 2015) lead to consequences in cheese perceptions by panelists. The ripening microflora determines the texture, cohesiveness, and rind thickness. Its population density also has an effect on cheese ripening: a less dense covering facilitates water exchange across the surface of the cheese, causing drying that increases the RH effect observed with higher DM and hardness

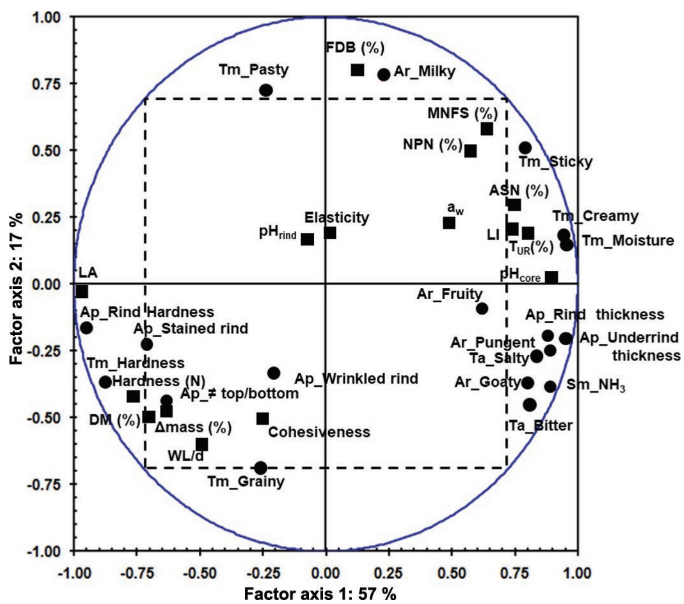

Figure 1. Principal component analysis of 19 sensory descriptors as active variables (●) and 16 physicochemical variables as supplementary variables (■) on the factor axes 1 and 2 with a confidence interval of 0.01. The square in dotted lines shows the projections of cosines equal to 0.70 onto the 2 axes. The variables for which the cosine was less than 0.70 (inside the square) were not significant. ASN = acid-soluble nitrogen (%); a_w = water activity; Co = cohesiveness; DM = DM content (g of dry cheese/100 g of wet cheese); El = elasticity; H = hardness (N); MNFS = moisture in nonfat solids (%); LA = lactate content (g/kg of wet cheese); LI = lipolytic index (mg of KOH/g); NPN = NPN (%); FDB = fat on dry basis (%); T_{UR} = thickness of underrind (%); Δmass = cheese mass loss (%); Δwt/d = weight loss (g) per day; Ap = appearance; Ar = aroma; Sm = smell; Ta = taste; Tm = texture in mouth.

as well as a more intense grainy texture in the mouth (Marcellino et al., 2001). It is also well known that microorganisms in cheese rind produce enzymes for protein and fat breakdown, resulting in considerable aroma compound production. Indeed, for example, *G. candidum* is known to produce caproic, caprylic, and capric acids (Gaborit et al., 2001; Leclercq-Perlat et al., 2007) that give cheese a pungent and goaty flavor (Gaborit et al., 2001; Boutrou and Guéguen, 2005). Yeasts also generate short- or medium-chain free fatty acids (C4:0–C12:0), giving a fruity and milky aroma. The ripening microflora also contribute to bitterness perception, ammonia intensity, and sulfur and fruity flavor (Boutrou and Guéguen, 2005).

As shown in Figure 2, on the factor axes 1 and 2 of the PCA of ripening condition runs on d 12, the runs carried out under 88% RH were mainly projected onto the bottom left negative side of the 1–2 factorial plan, whereas those performed under 98% RH were projected onto the upper right side. Moreover, the perception (e.g., rind hardness, appearance, and texture in mouth)

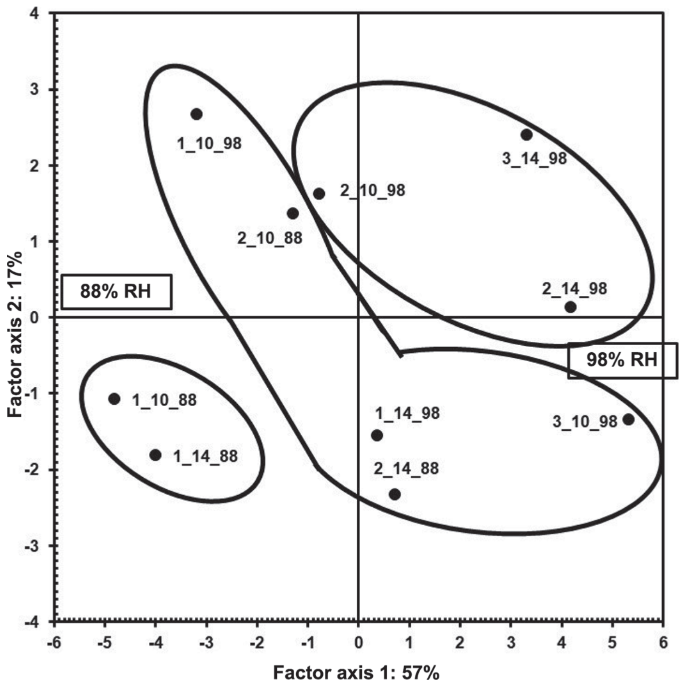

Figure 2. Principal component analysis of ripening condition runs on the factor axes 1 and 2. 1, 2, or 3 replicate runs; temperature = 10 or 14°C; relative humidity (RH) = 88 or 98%. The clusters in the boxes were defined from a hierarchical classical analysis on products from physicochemical and sensory variables based on Ward distance.

and physicochemical (DM, lactate content, hardness) criteria describing the driest and hardest texture were typical of cheeses ripened under 88% RH. In contrast, perception and physicochemical criteria typical of intensive ripening were linked to cheeses ripened under 98% RH. These results were in accordance with those of Leclercq-Perlat et al. (2015), who showed that the perception and physicochemical properties were highly dependent on temperature and RH. However, there is no visible effect of temperature in Figure 2. Indeed, cheeses of the third ripening run carried out under 10°C and 98% RH (3_10_98) were displayed on factor axis 1, close to the 3 runs carried out under 14°C and 98% RH. Moreover, those cheeses (3_10_98) were very different from the cheeses of 2 other runs achieved under 10°C and 98% in terms of perception. Those 3_10_98 cheeses were perceived as the most odorous in terms of ammonia. They also exhibited a thicker underrind, a softer rind, a less milky aroma, and a saltier and more bitter taste and their texture in the mouth was described as soft, very humid, very creamy, and not pasty.

This could be explained by the differences in cheese texture and DM content on d 0 for the cheeses ripened at 10°C under 98% of this third run. However, no temperature effect is visible in Figure 2. Temperature effect was highlighted by statistical analysis at 14°C only under 98% RH.

CONCLUSIONS

On d 0, the physicochemical variables were strongly dependent on artisanal Picodon cheese-making parameters. This huge effect of the daily production factor was highlighted on perception attributes and physicochemical variables after d 12 of ripening. Despite this, on d 12, these perception and physicochemical criteria were highly dependent on the RH used throughout ripening. Whatever the temperature, an increase in RH from 88 to 98% increased core pH, lactate consumption, and underrind thickening. In these conditions, DM content and hardness decreased due to the lowest cheese water loss. Many perception attributes scored the lowest. Indeed, the cheeses were too dry and hard. Their odor, appearance, and texture in the mouth were regarded as poorly ripened by cheese-makers. In contrast, an RH of 98% induced an intense ripening of the Picodon cheeses: the flavor was slightly ammonia and milky, and the texture in the mouth was sticky and creamy depending on underrind structure (underrind thickness, ASN, lipolytic index, core pH). Cheeses ripened at 14°C strengthened the RH effect. The perception and physicochemical criteria of the cheeses ripened at 14°C under 98% RH were indicative of overripened cheeses. Nevertheless, when the cheeses at the cell ripening input (d 0) were still very wet and soft, those ripened under 98% RH collapsed and were overripened with a liquid underrind; they could no longer be marketed under the PDO Picodon cheeses because of their perception and physicochemical compositions. These Picodon cheeses should be either returned to the dryer or ripened at 10°C under 88% RH. This study provides several suggestions for achieving a more effective and rational control of the ripening process in the case of Picodon cheeses: (1) slowing down or accelerating the ripening process in relation to the texture (hardness) and the DM content of the cheeses on d 0, and (2) correcting some of the existing flaws to make acceptable cheeses. However, to be able to define the optimal conditions of ripening, a more complete experimental design could be studied as shown by Leclercq-Perlat et al. (2012, 2015).

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