



**HAL**  
open science

## **Elaboration and characterisation of a miniature soft lactic goat cheese model to mimic a factory cheese**

Abirami Baleswaran, Christel Couderc, Marine Reyrolle, Mickael Le Béhec,  
Jean Dayde, Hélène Tormo, Gwénaëlle Jard

### ► **To cite this version:**

Abirami Baleswaran, Christel Couderc, Marine Reyrolle, Mickael Le Béhec, Jean Dayde, et al..  
Elaboration and characterisation of a miniature soft lactic goat cheese model to mimic a factory cheese.  
International Dairy Journal, 2023, 142, pp.105646. 10.1016/j.idairyj.2023.105646 . hal-04043904

**HAL Id: hal-04043904**

**<https://univ-pau.hal.science/hal-04043904v1>**

Submitted on 24 Mar 2023

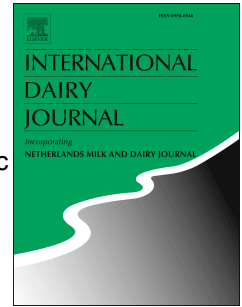
**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Journal Pre-proof

Elaboration and characterisation of a miniature soft lactic goat cheese model to mimic a factory cheese

Abirami Baleswaran, Christel Couderc, Marine Reyrolle, Mickael Le Behec, Jean Dayde, H el ene Tormo, Gw ena lle Jard



PII: S0958-6946(23)00065-1

DOI: <https://doi.org/10.1016/j.idairyj.2023.105646>

Reference: INDA 105646

To appear in: *International Dairy Journal*

Received Date: 25 July 2022

Revised Date: 9 March 2023

Accepted Date: 9 March 2023

Please cite this article as: Baleswaran, A., Couderc, C., Reyrolle, M., Le Behec, M., Dayde, J., Tormo, H., Jard, G., Elaboration and characterisation of a miniature soft lactic goat cheese model to mimic a factory cheese, *International Dairy Journal*, <https://doi.org/10.1016/j.idairyj.2023.105646>.

This is a PDF file of an article that has undergone enhancements after acceptance, such as the addition of a cover page and metadata, and formatting for readability, but it is not yet the definitive version of record. This version will undergo additional copyediting, typesetting and review before it is published in its final form, but we are providing this version to give early visibility of the article. Please note that, during the production process, errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

  2023 Elsevier Ltd. All rights reserved.

**Credit authorship contribution statement**

Abirami Baleswaran: Conceptualization, Methodology, Formal analysis, Investigation, Writing – Original Draft, Review & Editing, Visualization.

Christel Couderc: Methodology, Writing – Review & Editing, Supervision.

Jean Dayde: Writing – Review & Editing, Supervision.

Marine Reyrolle: Formal analysis, Writing – Review & Editing

Mickael Lebecqec: Formal analysis, Writing – Review & Editing

Hélène Tormo: Conceptualization, Writing – Review & Editing, Supervision, Project administration, Funding acquisition.

Gwenaëlle Jard: Conceptualization, Writing – Review & Editing, Supervision, Project administration, Funding acquisition.

1 **Elaboration and characterisation of a miniature soft lactic goat cheese model to mimic a**  
2 **factory cheese.**

3

4

5

6 Abirami Baleswaran<sup>a</sup>, Christel Couderc<sup>a</sup>, Marine Reyrolle<sup>b</sup>, Mickael Le Behec<sup>b</sup>, Jean Dayde<sup>a</sup>,

7 Hélène Tormo<sup>a, #</sup>, Gwénaëlle Jard<sup>a#\*</sup>

8

9

10

11 <sup>a</sup> *Université de Toulouse, Ecole d'Ingénieurs de Purpan, INPT, Toulouse, France*

12 <sup>b</sup> *Université de Pau et des Pays de l'Adour, E2S UPPA, CNRS, IMT Mines Ales, IPREM, Institut*  
13 *des sciences analytiques et de Physicochimie pour l'environnement et les Matériaux, UMR5254,*  
14 *Hélioparc, 2 avenue Président Angot, 64053, PAU cedex 9, France*

15

16

17

18 \*Corresponding author

19 *E-mail address: [gwenaelle.jard@purpan.fr](mailto:gwenaelle.jard@purpan.fr) (G. Jard)*

20

21

22

23 <sup>#</sup> Hélène Tormo and Gwénaëlle Jard contributed equally to this work

24

25

---

26 ABSTRACT

27

28 Although soft lactic goat cheeses are widely produced in France, there is little information  
29 available in the literature about them and no miniature model for this kind of cheese has yet been  
30 proposed. In this study, a miniature soft lactic goat cheese model was compared with equivalent  
31 factory cheese to use it as a reliable model for this cheese family. The composition of the cheeses  
32 was compared at four key stages of the production process using microbiological,  
33 physicochemical and Sift-MS volatilome analysis. The compositions of the model and factory  
34 cheeses were found to be similar until the ripening step, but some differences were observed on  
35 ripened cheeses. Moreover, under carefully monitored laboratory conditions, the variability  
36 across batches of the model cheese was reduced. This miniature soft lactic goat cheese could  
37 therefore be used as a reliable model to study the aspects of the same cheese type.

38

---

39

40

## 41 1. Introduction

42

43 Pilot-scale cheesemaking experiments under controlled conditions are costly and time-  
44 consuming in contrast to experiments at the laboratory scale (Shakeel-Ur-Rehman, Fox,  
45 McSweeney, Madkor, & Farkye, 2001).

46 Protocols for the preparation of miniature cheese models, produced in laboratory-  
47 controlled conditions, where key properties of the miniature cheese models resemble those of  
48 conventionally manufactured cheeses, have been proposed for fresh cheeses (Hynes, Ogier, &  
49 Delacroix-Buchet, 2000), soft cheeses, semi-hard cheeses (Shakeel-Ur-Rehman, McSweeney, &  
50 Fox, 1998) and hard cheeses (Antonsson, Ardö, Nilsson, & Molin, 2002; Vélez, Perotti, Rebechi,  
51 & Hynes, 2015). However, despite the importance of soft lactic cheeses (simultaneous  
52 acidification and rennet coagulation), no comparable procedure has yet been described for them.  
53 The microbiological, physicochemical, and sensorial characteristics of a few factory soft lactic  
54 goat cheeses have been described (Couderc et al., 2022; Lucas et al., 2006), but not their volatile  
55 profiles. Gas chromatography-mass spectrometry (GC-MS) is generally used to identify and  
56 quantify volatile compounds, although this approach is costly and time-consuming. Selected ion  
57 flow tube-mass spectrometry (Sift-MS), a recently developed alternative approach, allows faster  
58 analysis and has already shown promising results for cheese aroma characterisation (Langford,  
59 Padayachee, McEwan, & Barringer, 2019; Reyrolle et al., 2022).

60 The purpose of this study was to establish a reliable model for the soft lactic goat cheese  
61 family and compare it with its factory equivalent. The compositions of the model and factory  
62 cheeses were compared using microbiological, physicochemical and Sift-MS volatilome analysis.

63

## 64 2. Materials and methods

65

### 66 2.1. Production of factory and miniature model cheese

67

68 Three batches of raw goats' milk were collected from "Les Fermiers du Rocamadour"  
69 (Alvignac, France) at different times of the year to make three batches of miniature models  
70 (produced in laboratory-controlled conditions) and factory cheeses. Each batch of milk was split  
71 into two parts; 180 L were used directly to factory cheese production at "Les Fermiers du  
72 Rocamadour" and 2 L were transferred into 250 mL bottles and frozen at  $-20\text{ }^{\circ}\text{C}$  for the  
73 subsequent production of the miniature models.

74 Factory cheeses were produced in accordance with Rocamadour PDO cheese  
75 specifications (Legifrance, 2014), as followed by Couderc et al. (2022). The process is outlined in  
76 Fig. 1A.

77 Model cheese was produced under laboratory conditions based on the factory cheese  
78 process (Fig. 1B). Frozen raw goats' milk was thawed for one day at  $4\text{ }^{\circ}\text{C}$ , pasteurised ( $85\text{ }^{\circ}\text{C}$ , 5  
79 min) and cooled to  $35\text{ }^{\circ}\text{C}$ . The same concentrations of starter and ripening microorganisms were  
80 used as in the factory process.  $\text{CaCl}_2$  (Durcigel, Coquard, Villefranche-sur-Saône, France) was  
81 added at  $0.4\text{ mL L}^{-1}$  and a short maturation period of 45 min at  $25\text{ }^{\circ}\text{C}$  was done. Once the pH had  
82 decreased by 0.2 units, rennet ( $100\text{ mL } 100\text{ L}^{-1}$  of  $520\text{ mg L}^{-1}$  chymosin; Coquard) was added.  
83 The milk was then distributed into 50 mL tubes and incubated at  $25\text{ }^{\circ}\text{C}$  for 22 h.

84 As described in the protocols of previously produced model cheeses, centrifugation was  
85 used to separate the curd from the whey (Hynes et al., 2000; Shakeel-Ur-Rehman et al., 1998;  
86 Van Tassell, Ibarra-Sánchez, Takhar, Amaya-Llano, & Miller, 2015). To be in accordance with  
87 Rocamadour PDO cheese specifications (minimum 31% of dry matter and 0.6–0.8% of salt

88 content; Legifrance, 2014), three conditions of centrifugation and three conditions of salting had  
89 previously been tested to select the following parameters (data not shown). The tube was  
90 centrifuged for 3 h 30 at 25 °C at 4430 rpm, the whey then discarded and the curd salted with a  
91 185 mg mL<sup>-1</sup> NaCl brine solution. The curd was placed in a custom-built mould (diameter, 38  
92 mm; height, 10 mm, Verres Vagner, Toulouse, France), 3.5 times smaller than those used for the  
93 factory cheeses but with the same diameter/height ratio (Fig. 2A).

94 The resulting cheese was then placed in a miniature (175 cm<sup>3</sup>) ripening cellar with two air  
95 inlets to insure proper ventilation (Fig. 2B). The mini cellar was placed in a temperature-  
96 controlled refrigerated container. A Petri dish with sterile cotton wool soaked in sterile water was  
97 placed at the bottom of the cellar to regulate relative humidity (RH). Temperature and RH were  
98 monitored every 2 h during the ripening process using a LogTag recorder (Trix8, LogTag,  
99 France) placed in the cellar.

100 All the equipment used were autoclaved or disinfected and UV-treated. Fig. 1B illustrates  
101 the two stages of the ripening process: (i) one day of ripening at  $13 \pm 0.2$  °C and  $92.8 \pm 0.8$  % RH  
102 and (ii) 6 days at  $10 \pm 0.1$  °C and  $94.5 \pm 0.5$ % RH. The cheeses were turned once a day  
103 throughout the ripening process.

104 Samples of the model and factory cheeses were collected at four key stages of the  
105 production process: before salting, after salting, on the first day of ripening and at the end of the  
106 ripening stage (indicated with asterisks in Fig. 1).

107

## 108 2.2. *Cheese composition analysis*

109

### 110 2.2.1. *Physicochemical analysis*



111 Physicochemical analyses were performed on three factory cheeses and three model  
112 cheeses stored at 4 °C at all four stages of all three production batches. Dry matter (DM), fat (FC)  
113 and salt (S) contents were analysed according to NF EN ISO 5534, NF V04-287 and NF EN ISO  
114 5943 standards, respectively.

115 The salt-in-moisture (S/M) and moisture on a fat-free basis (MFFB) contents were  
116 calculated as follows:

$$117 \quad S/M = (\%S) / (100 - \%DM)$$

$$118 \quad MFFB = [(100 - \%DM) / (100 - \%FC)] \times 100$$

119 All analyses for the factory cheeses and the fat and salt content measurements for the  
120 model cheeses were performed by Agrolabs (Auch, France). The DM and pH measurements for  
121 the model cheeses were performed internally. The pH values were measured using a HQ11d pH  
122 meter (Hach, France).

123

#### 124 2.2.2. *Microbiological analysis*

125 Microbiological analyses were performed on three ripened factory cheeses and three  
126 ripened model cheeses stored at 4 °C of three production batches. Aerobic mesophilic bacteria  
127 levels were enumerated on plate count agar (PCA; Biokar, France) supplemented with skimmed  
128 milk powder and, yeasts and moulds counts were enumerated on oxytetracycline glucose agar  
129 (OGA; Biokar). Serial decimal dilutions in buffered peptone (Biomérieux, France) were prepared  
130 and 0.1 mL samples of appropriate dilutions were plated on appropriate media. The PCA plates  
131 were incubated at 30 °C for 48 h and the OGA plates were incubated at 25 °C for 5 days. The  
132 same analyses were performed in Agrolabs (Auch, France) for the factory cheeses and internally  
133 for the model cheeses.

134

### 135 2.2.3. Sift-MS analysis

136 Sift-MS analysis was performed on three ripened factory cheeses and three ripened  
137 miniature cheeses from a single production batch, that were vacuum-packed and stored at  $-20\text{ }^{\circ}\text{C}$ .  
138 The sample preparation protocol was inspired by Taylor, Wick, Castada, Kent, and Harper  
139 (2013). Five grams ( $\pm 0.3\text{ g}$ ) of ripened cheese was placed in a 1 L bottle and sealed with a  
140 Teflon cap. The bottle was then heated at  $40\text{ }^{\circ}\text{C}$  for 1 h before Sift-MS analysis to allow the  
141 headspace to equilibrate.

142 The VOCs released by the cheese samples were analysed using a Sift-MS Voice 200 Ultra  
143 device (Syft Technologies Ltd., New Zealand) using positive soft ionising precursor ions ( $\text{H}_3\text{O}^+$ ,  
144  $\text{NO}^+$  and  $\text{O}_2^+$ ). After each analysis, a blank test was performed using an empty bottle.  
145 Immediately after incubation, the headspace of the sample was introduced via a calibrated  
146 capillary at a sampling flowrate of  $20\text{ nmL min}^{-1}$  into the reaction chamber (a flow tube at  $120$   
147  $^{\circ}\text{C}$  and  $0.07\text{ kPa}$ ) with nitrogen ( $180\text{ nmL min}^{-1}$ ) as the carrier gas. The measurements were  
148 performed in full scan mode from 15 to 250  $m/z$  with count rates (signal intensity in counts per  
149 second) calculated for each  $m/z$  unit.

150 The Sift-MS data were acquired and analysed using LabSyft v.1.6.2. (Syft Technologies,  
151 New Zealand). Four full mass scans were recorded for each sample but only the last three were  
152 analysed.

153 The data were co-added and pre-processed as described by Reyrolle et al. (2022). The  
154 VOC profiles of the model and factory cheese samples were compared based on the reagent ion–  
155 product ion combinations of 36 VOCs previously identified in goat cheeses (Supplementary  
156 material Table S1) (Bontinis, Mallatou, Pappa, Massouras, & Alichanidis, 2012; Delgado,  
157 González-Crespo, Cava, & Ramírez, 2011; Hayaloglu, Yasar, Tolu, & Sahingil, 2013).

158 The volatile fingerprints of the model and factory cheeses were compared using the mixOmics R  
159 package (Rohart, Singh, Gautier, & Cao, 2017).

160

### 161 2.3. *Statistical analysis*

162

163 Gross cheese compositions were expressed as means and standard deviations over the three  
164 production runs and four sampling stages and compared between the factory and model cheeses  
165 using Kruskal-Wallis tests.

166 VOC product ion intensities were compared between the factory and the model cheeses  
167 with Wilcoxon signed-rank tests. Homogeneity of variance was verified using Levene's test. The  
168 threshold for statistical significance were set at  $p < 0.05$ .

169

## 170 **3. Results and discussion**

171

172 Regarding physicochemical parameters (Table 1), fat and salt contents of the model  
173 cheeses were similar to those of the factory cheeses at all stages. For the other parameters, they  
174 were similar until the first day of ripening. Indeed, during ripening, few differences were  
175 recorded between the two types of cheeses concerning the dry matter contents, the moisture on a  
176 fat-free basis and the pH values. The lower values of the moisture on a fat-free basis (higher dry  
177 matter content) of the model cheeses could be explained by lower relative humidity during  
178 ripening. At the end of ripening, the pH value of the model cheeses was also significantly higher  
179 than those of the factory cheeses, showing more intense deacidifying microbial activity in the  
180 model cheeses. In fact, increases in pH value during ripening can be due to the production of  
181 ammonia and various amino acids by proteolysis, and by the consumption of the lactic acid by

182 moulds and yeasts (which are the main deacidifying microorganisms in cheeses) (Bonaiti,  
183 Latrille, & Corrieu, 2004; Fox, 1989). This was confirmed by the fact that after ripening, the  
184 factory cheeses had substantially lower levels of yeasts, such as *Debaryomyces hansenii*, than the  
185 model cheeses ( $6.60 \pm 0.47$  versus  $2 \log_{10} \text{cfu g}^{-1}$ , respectively, Table 2). Nonetheless, the model  
186 cheeses' levels of aerobic mesophilic bacteria and *Geotrichum candidum* were comparable with  
187 those of the factory cheeses. The different microbiological compositions of cheeses could explain  
188 the rise of the pH value that was more important in the model cheeses during ripening (+0.7  
189 versus +0.3 units of pH for the model and factory cheeses, respectively). Moreover, this  
190 observation was not surprising since in the case of model cheeses, the microbial contamination of  
191 milk and environment are almost negligible (pasteurised milk, sterile mini cellar for the ripening)  
192 compared with factory production conditions. These microorganisms, and especially *G.*  
193 *candidum* that could be present in the factory ripening room's environment, may play an  
194 important role in the inoculation of the fresh cheese. *G. candidum*'s high and early presence in  
195 factory cheeses may make it harder for other yeasts to develop during ripening. Indeed, it is  
196 known that *G. candidum* could inhibit *D. hansenii* during ripening (Mounier et al., 2008).

197 The volatile fingerprints of the factory and model cheeses, given by the average intensities  
198 of 119 product ions (associated with the 36 selected VOCs, Supplementary material Table S1),  
199 are compared in Fig. 3. Only 21/119 product ions intensities differed significantly between the  
200 factory and model cheeses ( $p < 0.05$ , Wilcoxon tests, indicated by asterisks in Fig. 3 and  
201 Supplementary material Table S1), showing a relatively similar cheese VOCs composition.  
202 Moreover, a significant heterogeneity of variance between samples was observed for 3/119 model  
203 cheeses product ions and 9/119 factory cheeses product ions ( $p < 0.05$ , Levene test,  
204 Supplementary material Table S2). Therefore, the level of repeatability is higher on model

205 cheeses than on factory cheeses, certainly due to pasteurised milk used to make the model  
206 cheeses.

207         The gross composition of the ripened model cheese presented in our study is similar to that  
208 of soft lactic cheeses previously characterised (Gaborit, Menard, & Morgan, 2001; Raynal-  
209 Ijutovac, Pape, Gaborit, & Barrucand, 2011; Sablé, Portrait, Gautier, Letellier, & Cottenceau,  
210 1997) and could therefore be used as a reliable model for this cheese type, for which a model has  
211 never been described in literature.

212

#### 213 **4. Conclusion**

214

215         In this study, a miniature soft lactic goat cheese model was elaborated and compared with  
216 a factory cheese, based on microbiological, physicochemical and Sift-MS volatilome analysis.  
217 The model cheese has a similar composition to the factory cheese until ripening and differed on  
218 non-*Geotrichum candidum* yeasts, moisture on a fat-free basis levels and pH values for ripened  
219 cheese. During ripening, less variability was recorded in the model cheese between production  
220 batches compared with the factory cheese. This model should therefore facilitate future studies on  
221 the impact of various factors on quality of soft lactic cheeses.

222

#### 223 **Acknowledgments**

224

225         The authors thank Sebastien Fau and Benoit Bonizzoni from “Les Fermiers du  
226 Rocamadour” for their technical support during the cheesemaking experiments, Leticia Vitola  
227 Pasetto for her help with Sift-MS analysis, and to Occitanie Region for funding the project.

228

229 **References**

- 230
- 231 Antonsson, M., Ardö, Y., Nilsson, B. F., & Molin, G. (2002). Screening and selection of  
232 *Lactobacillus* strains for use as adjunct cultures in production of semi-hard cheese. *Journal*  
233 *of Dairy Research*, *69*, 457–472.
- 234 Bonaiti, C., Latrille, E., & Corrieu, G. (2004). Deacidification by *Debaryomyces hansenii* of  
235 smear soft cheeses ripened under controlled conditions : relative humidity and temperature  
236 influences. *Journal of Dairy Science*, *87*, 3976–3988.
- 237 Bontinis, T. G., Mallatou, H., Pappa, E. C., Massouras, T., & Alichanidis, E. (2012). Study of  
238 proteolysis, lipolysis and volatile profile of a traditional Greek goat cheese (Xinotyri)  
239 during ripening. *Small Ruminant Research*, *105*, 193–201.
- 240 Couderc, C., Caillaud, M., Jard, G., Raynaud, C., Cocaign-bousquet, M., & Daveran-mingot, M.  
241 (2022). Harnessing diversity of *Lactococcus lactis* from raw goat milk : Design of an  
242 indigenous starter for the production of Rocamadour, a French PDO cheese. *International*  
243 *Journal of Food Microbiology*, *379*, Article 109837.
- 244 Delgado, F. J., González-Crespo, J., Cava, R., & Ramírez, R. (2011). Formation of the aroma of a  
245 raw goat milk cheese during maturation analysed by SPME-GC-MS. *Food Chemistry*, *129*,  
246 1156–1163.
- 247 Fox, P. (1989). Proteolysis during cheese manufacture and ripening. *Journal of Dairy Science*,  
248 *72*, 1379–1400.
- 249 Gaborit, P., Menard, A., & Morgan, F. (2001). Impact of ripening strains on the typical flavour of  
250 goat cheeses. *International Dairy Journal*, *11*, 315–325.
- 251 Hayaloglu, A. A., Yasar, K., Tolu, C., & Sahingil, D. (2013). Characterizing volatile compounds  
252 and proteolysis in Gokceada artisanal goat cheese. *Small Ruminant Research*, *113*, 187–

- 253 194.
- 254 Hynes, E., Ogier, J. C., & Delacroix-Buchet, A. (2000). Protocol for the manufacture of  
255 miniature washed-curd cheeses under controlled microbiological conditions. *International*  
256 *Dairy Journal*, 10, 733–737.
- 257 Langford, V. S., Padayachee, D., McEwan, M. J., & Barringer, S. A. (2019). Comprehensive  
258 odorant analysis for on-line applications using selected ion flow tube mass spectrometry  
259 (SIFT-MS). *Flavour and Fragrance Journal*, 34, 393–410.
- 260 Legifrance. (2014). *Décret n°2014-1150 du 7 octobre 2014*. 1–14. Retrieved from  
261 [https://info.agriculture.gouv.fr/gedei/site/bo-agri/document\\_administratif-ab406329-e35e-](https://info.agriculture.gouv.fr/gedei/site/bo-agri/document_administratif-ab406329-e35e-4155-adb7-c276fbba1221/telechargement)  
262 [4155-adb7-c276fbba1221/telechargement](https://info.agriculture.gouv.fr/gedei/site/bo-agri/document_administratif-ab406329-e35e-4155-adb7-c276fbba1221/telechargement)
- 263 Lucas, A., Rock, E., Chamba, J. F., Verdier-Metz, I., Brachet, P., & Coulon, J. B. (2006).  
264 Respective effects of milk composition and the cheese-making process on cheese  
265 compositional variability in components of nutritional interest. *Lait*, 86, 21–41.
- 266 Mounier, J., Monnet, C., Vallaeys, T., Arditi, R., Sarthou, A., Hélias, A., et al. (2008). Microbial  
267 interactions within a cheese microbial community. *Applied and Environmental*  
268 *Microbiology*, 74, 172–181.
- 269 Raynal-ljutovac, K., Pape, M. Le, Gaborit, P., & Barrucand, P. (2011). French goat milk cheeses :  
270 An overview on their nutritional and sensorial characteristics and their impacts on  
271 consumers ' acceptance. *Small Ruminant Research*, 101, 64–72.
- 272 Reyrolle, M., Ghislain, M., Bru, N., Vallverdu, G., Pigot, T., Desauziers, V., et al. (2022).  
273 Volatile fingerprint of food products with untargeted SIFT-MS data coupled with  
274 mixOmics methods for profile discrimination: Application case on cheese. *Food*  
275 *Chemistry*, 369, Article 130801.
- 276 Rohart, F., Singh, A., Gautier, B., & Cao, K.-A. L. C. (2017). MixOmics : An R package for

- 277 omics feature selection and multiple data integration. *PLOS Computational Biology*, 13,  
278 Article 1005752.
- 279 Sablé, S., Portrait, V., Gautier, V., Letellier, F., & Cottenceau, G. (1997). Microbiological  
280 changes in a soft raw goat's milk cheese during ripening. *Enzyme and Microbial  
281 Technology*, 21, 212–220.
- 282 Shakeel-Ur-Rehman, Fox, P. F., McSweeney, P. L. H., Madkor, S. A., & Farkye, N. Y. (2001).  
283 Alternatives to pilot plant experiments in cheese-ripening studies. *International Journal of  
284 Dairy Technology*, 54, 121–126.
- 285 Shakeel-Ur-Rehman, McSweeney, P. L. H., & Fox, P. F. (1998). Protocol for the manufacture of  
286 miniature cheeses. *Lait*, 78, 607–620.
- 287 Taylor, K., Wick, C., Castada, H., Kent, K., & Harper, W. J. (2013). Discrimination of swiss  
288 cheese from 5 different factories by high impact volatile organic compound profiles  
289 determined by odor activity value using selected ion flow tube mass spectrometry and odor  
290 threshold. *Journal of Food Science*, 78, 1509–1515.
- 291 Van Tassell, M. L., Ibarra-Sánchez, L. A., Takhar, S. R., Amaya-Llano, S. L., & Miller, M. J.  
292 (2015). Use of a miniature laboratory fresh cheese model for investigating antimicrobial  
293 activities. *Journal of Dairy Science*, 98, 8515–8524.
- 294 Vélez, M. A., Perotti, M. C., Rebechi, S. R., & Hynes, E. R. (2015). Short communication: A  
295 new minicurd model system for hard cooked cheeses. *Journal of Dairy Science*, 98, 3679–  
296 3683.
- 297



## Figure legends

**Fig. 1.** Production flow charts for (A) factory and (B) miniature model soft lactic goat cheeses; asterisks (\*) indicate sample collection stages.

**Fig. 2.** Photographs of (A) a miniature model cheese and (B) the miniature cheese ripening cellar.

**Fig. 3.** Volatile fingerprints of factory (blue) and miniature model (orange) cheese. Radar plots of the Sift-MS intensities of 119 product ions associated with 36 selected goat cheese VOCs described in the literature (for better readability, only a subset of the ions are labelled). Peak intensities correspond to production ion abundance on a logarithmic scale. The dashed lines and shaded areas correspond to means (blue, factory; orange, model) and standard deviations, respectively. The asterisks correspond to 21 product ions differing significantly between factory and model cheese.

**Table 1**

Physicochemical characteristics of miniature model and factory cheese at four production stages. <sup>a</sup>

Parameter	Cheese type	Before salting	After salting	1 <sup>st</sup> day of ripening	End of ripening
Dry matter (%)	Factory	38.3 ± 2.5 <sup>a</sup>	36.9 ± 2.0 <sup>a</sup>	36.8 ± 1.7 <sup>a</sup>	38.2 ± 2.6 <sup>a</sup>
	Model	38.8 ± 2.2 <sup>a</sup>	39.6 ± 1.7 <sup>a</sup>	<b>40.7 ± 1.1<sup>b</sup></b>	<b>42.1 ± 0.8<sup>b</sup></b>
Fat content (%)	Factory	19.8 ± 1.5 <sup>a</sup>	18.6 ± 1.4 <sup>a</sup>	18.4 ± 1.6 <sup>a</sup>	19.8 ± 2.6 <sup>a</sup>
	Model	18.4 ± 2.7 <sup>a</sup>	18.8 ± 0.9 <sup>a</sup>	19.1 ± 0.6 <sup>a</sup>	21.0 ± 0.8 <sup>a</sup>
Salt content (%)	Factory	nd	0.9 ± 0.1 <sup>a</sup>	0.9 ± 0.1 <sup>a</sup>	1.0 ± 0 <sup>a</sup>
	Model	nd	0.9 ± 0.1 <sup>a</sup>	0.9 ± 0.1 <sup>a</sup>	1.1 ± 0.1 <sup>a</sup>
Salt-in-moisture (%)	Factory	nd	1.4 ± 0.2 <sup>a</sup>	1.3 ± 0.1 <sup>a</sup>	1.6 ± 0.1 <sup>a</sup>
	Model	nd	1.6 ± 0 <sup>a</sup>	<b>1.6 ± 0<sup>b</sup></b>	<b>1.8 ± 0<sup>b</sup></b>
Moisture on fat-free basis (%)	Factory	77.0 ± 1.8 <sup>a</sup>	77.5 ± 1.2 <sup>a</sup>	77.4 ± 0.8 <sup>a</sup>	77.0 ± 1.0 <sup>a</sup>
	Model	75.2 ± 1.4 <sup>a</sup>	<b>74.3 ± 1.2<sup>b</sup></b>	<b>73.2 ± 0.9<sup>b</sup></b>	<b>73.3 ± 0.2<sup>b</sup></b>
pH	Factory	4.4 ± 0 <sup>a</sup>	4.4 ± 0 <sup>a</sup>	4.4 ± 0 <sup>a</sup>	4.7 ± 0.3 <sup>a</sup>
	Model	4.4 ± 0.1 <sup>a</sup>	4.5 ± 0.1 <sup>a</sup>	4.5 ± 0 <sup>a</sup>	<b>5.2 ± 0.1<sup>b</sup></b>

<sup>a</sup> Data are expressed as mean ± standard deviation (n = 3); different superscript letters indicate significant differences between factory and model samples ( $p < 0.05$ ); values in bold for the model cheese are significantly different from those measured for the factory cheese at the same stage.

**Table 2**

Microbial counts in the miniature model and factory cheese at the end of the ripening stage.<sup>a</sup>

Microorganism	Cheese type	Counts
Aerobic mesophilic bacteria level	Factory	8.92 ± 0.10 <sup>a</sup>
	Model	9.11 ± 0.45 <sup>a</sup>
<i>Geotrichum candidum</i>	Factory	8.99 ± 2.01 <sup>a</sup>
	Model	7.89 ± 0.03 <sup>a</sup>
Other yeasts	Factory	<2 <sup>a</sup>
	Model	<b>6.60 ± 0.47<sup>b</sup></b>

<sup>a</sup> Data (in log<sub>10</sub> cfu g<sup>-1</sup>) are expressed as mean ± standard deviation (n = 3); different superscript letters indicate significant differences between factory and model samples (*p* < 0.05); values in bold for the model cheese are significantly different from those measured for the factory cheese at the same stage.

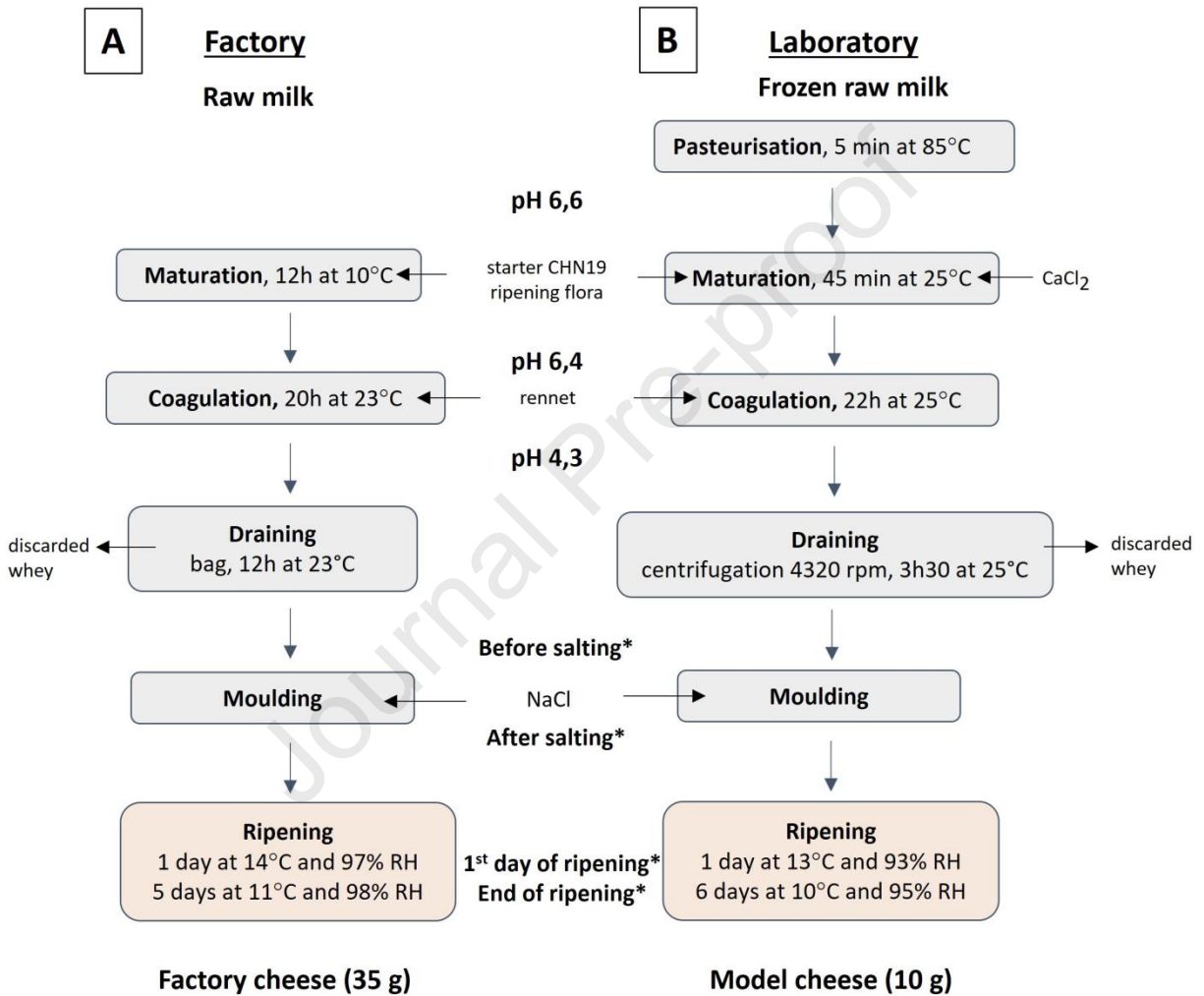


Figure 1

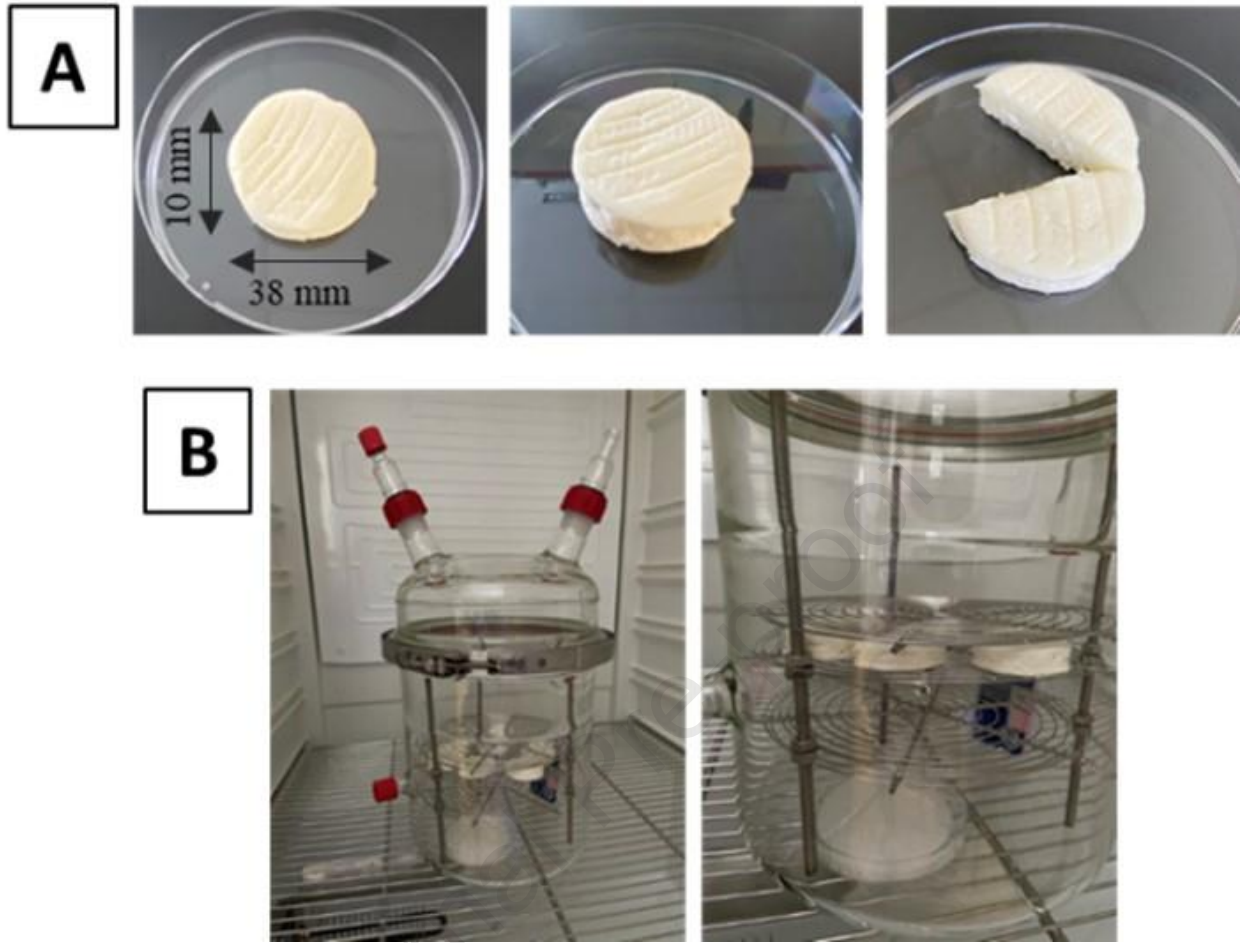


Figure 2

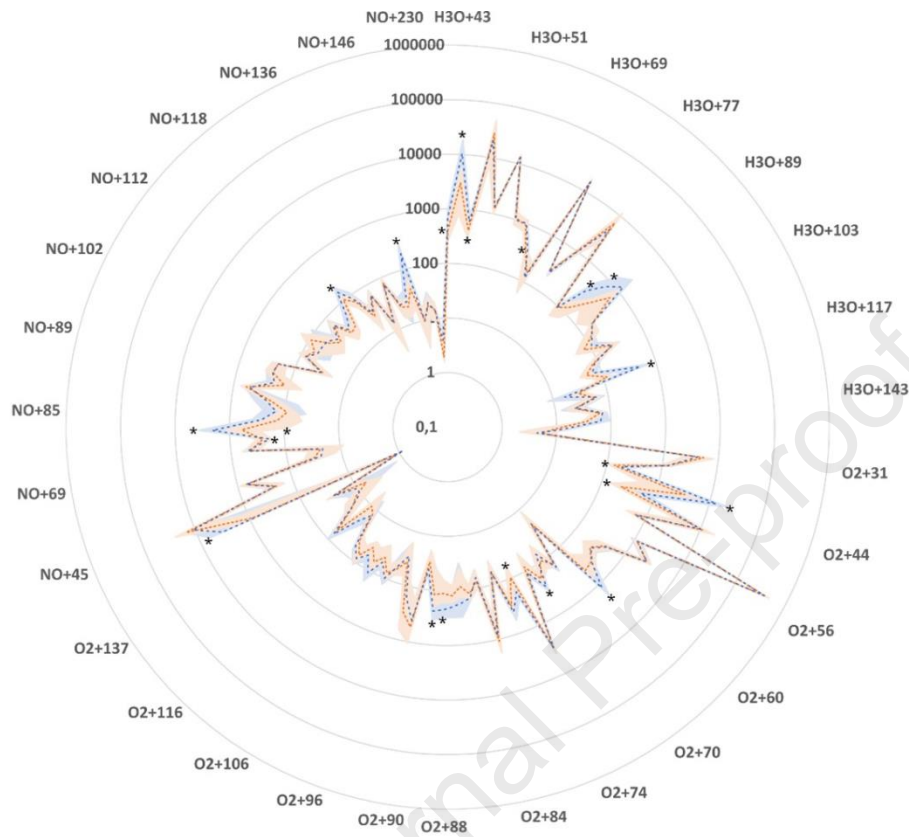


Figure 3

**Declaration of interests**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Journal Pre-proof