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Summary — A cheese model used to perform sensory evaluation of flavour compounds extracted from various cheese varieties was made with caseins, low heat milk powder, deodorized milk fat, NaCl and rennet. Its composition and physicochemical properties were close to mature hard cheese, apart from a lower dry matter content and sodium concentration, and a higher lactose concentration. Its preparation was established in order to avoid drainage for at least 24 h, which should allow the incorporation of not only some lipophilic substances such as aromas but also some water-soluble substances such as amino acids and peptides. The rheological behaviour of the cheese model measured by a compression test had a pattern similar to some hard cheeses but with much lower values and its flavour was evaluated as neutral. Compared to some lightly flavoured cheeses, this cheese model was found to be slightly salty, bitter or sour, and had only a light milky aroma.

cheese model / composition / rheology / sensory evaluation

Résumé — Production d'un modèle fromage pour des évaluations sensorielles de composés aromatiques. *Un modèle fromager permettant de réaliser des évaluations sensorielles de composés aromatiques isolés à partir de diverses variétés de fromages a été fabriqué avec de la caséine, de la poudre de lait faiblement chauffé, de la matière grasse laitière désodorisée, du chlorure de sodium et de la présure. Sa composition et ses propriétés physicochimiques étaient semblables à celles d'un fromage âgé, mis à part les taux plus faibles de matière sèche et de sodium, et une concentration en lactose plus importante. Sa préparation a été établie dans le but d'éviter un égouttage pendant au moins 24 h, ce qui a permis l'incorporation non seulement de substances lipophiles comme des arômes mais aussi de composés hydrosolubles tels que des acides aminés et des peptides. Le comportement rhéologique du fromage modèle, mesuré par un test de compression, a un profil similaire à celui de fromages à pâte dure et sa flaveur a été évaluée comme étant neutre. Par comparaison avec des fromages ayant peu de flaveur, ce modèle fromage a été décrit comme légèrement salé, amer ou acide, et avait seulement un léger arôme de lait.*

fromage modèle / composition / rhéologie / évaluation sensorielle

INTRODUCTION

The flavour of cheeses has been studied extensively during the last 20 years and a great number of volatile compounds have been identified (Adda and Dumont, 1974; Groux and Moinas, 1974; Dumont *et al*, 1974; Cuer *et al*, 1979; Bosset and Liardon, 1984; Brennand *et al*, 1989; Gallois and Langlois, 1990). Concerning taste, some reports have shown that the water-soluble fraction contains compounds such as peptides, amino acids and salts (Biede and Hammond, 1979; McGugan *et al*, 1979; Aston and Creamer, 1986) which have a great flavour intensity. These food constituents are important for their sensory properties. Therefore, crude extracts, partially purified fractions or pure compounds have been subject to sensory evaluation in order to determine their organoleptic impact or their threshold value (Kirimura *et al*, 1969; Schiffman and Engelhard, 1976; Kato *et al*, 1989). Most of these sensory experiments were conducted using products dissolved in water or in a water–ethanol mixture for the less polar compounds. This process is open to criticism because the evaluated molecules are not studied in the same environment as in the original food product: interactions with macromolecules such as proteins, lipids or polysaccharides, variations in pH and ionic strength may affect the headspace concentration of the compounds and thus induce changes in perception. In some cases, simple matrices such as water–ethanol are sufficient because in the original product such as beer, for instance (Abbott *et al*, 1993), the interactions between the volatile and the non-volatile constituents are weak. However, this is not the case for cheese, where the representativeness of the aroma extract is better when it is incorporated in an oil–water emulsion rather than in water (Etiévant *et al*, 1994). Therefore, it is necessary to taste them in a medium similar to the food matrix but as bland as possible. This approach has been already carried out for fruit products, for example, tomatoes (Petro-Turza and Teleky-Vamossi, 1989), fruit juice (Casimir and Whitfield, 1978) and particularly for wine (Selfridge and Amerine, 1978; Edwards *et al*, 1985; Etiévant *et al*, 1989; Maga, 1990; Martin *et al*, 1991). It is surprising that for dairy products, to our knowledge, only Roger *et al* (1988) tried to incorporate 2-phenyl ethanol and its esters in a cheese model to determine their threshold value in cheese. This cheese model was made with a mixture of concentrated skimmed milk retentate, milk fat and flavour compounds, and was subjected to the action of rennet. Our preliminary experiments showed that this cheese exhibited an intense milky flavour due to the crude dairy products used. Several cheese models are described in the literature (Ernstrom *et al*, 1980; Rubin and Bjerre, 1983a, b; Moran *et al*, 1989; Stampanoni and Noble, 1991; Tamime *et al*, 1991; Smit *et al*, 1995), but the constituents used have an intense flavour and, moreover, these cheese models are subject to draining which leads to the loss of hydrosoluble compounds.

Our target was to develop a cheese model which was easy to prepare, bland and not susceptible to draining. In this paper, we describe the method of preparation of a new cheese model, its chemical, rheological and sensory properties, and some applications for the study of goat cheese flavour.

MATERIALS AND METHODS

Materials

Low heat milk powder (MP) was made according to the process described by Schuck *et al* (1994) and obtained from the Laboratoire de recherches technologie laitière (LRTL, INRA, Rennes, France). Native calcium phosphocaseinate (NCPP) was prepared by membrane microfiltration (Pierre *et al*, 1992) and obtained from LRTL. Deodorized anhydrous milk fat (MF) was graciously supplied by Corman SA (Goe, Belgium). Sodium chloride, L-glutamic acid, sodium L-glutamate, L-leucine and L-isoleucine were purchased from Merck (Darmstadt, Germany); glucono delta lactone (GDL) was obtained from Fluka (St Quentin Fallavier, France). Food quality amino acids were purchased from Rexim SA (Courbevoie, France). 4-Ethyl octanoic acid was synthesized by Henry, INSA (Lyon, France) (unpublished result) and 4-methyl octanoic acid was obtained from IFF (Dijon, France).

All cheeses mentioned in this paper were bought at local markets, apart from the goat cheese called "Bouton de culotte" bought at the agronomic school of Davayé (Mâcon, France).

Procedure for preparing the cheese model

All the properties were measured on a cheese model (CM) prepared according to the following procedure (fig 1): six hundred ml of pure water (60%) and 190 g of MF (19%) were prewarmed at 50°C. First, 30 g of MP (3%) and 2 g of NaCl (0.2%) were dissolved in warm water. Then, 170 g NCPP (17%) were added in 6 g aliquots to the solution. Between each addition, the preparation was mixed with a Waring Blender® at 18 500 rpm for 3–4 s. After this, 190 g of warm MF and 8 g of GDL (0.8%) were successively added, mixed in the same manner and held at 33°C for 2.5 h. Lastly, 0.15 ml of rennet extract containing 520 mg l^{-1} of chymosin (Sanofi Bio-Industries, Paris, France), diluted in 9 volumes of water, were added; the mixture was quickly homogenized, held at 33°C for 1 h and stored at 15°C until use.

When exogenous single compounds or mixtures were added, the process was modified as follows: NCPP, MP and NaCl were mixed with the prewarmed water, held overnight at 4°C, warmed at 50°C and mixed with the prewarmed MF. The hydrosoluble compounds were premixed in 20% of total water containing 1% of fatty acids sucrose ester (food quality emulsifier SP70, Sisterna, Roosendaal, Netherlands), and added just before the addition of MF. Liposoluble compounds, such as volatile compounds, were premixed with MF, but the emulsifier was always added in order to make comparisons.

Analytical methods

All the quantitative measurements were repeated 5 times by 3 inexperienced operators. The pH of the cheese model (CM) was controlled with a pH meter equipped with a special electrode for hard paste. Dry matter was weighed after heating 5 g of CM at 103°C for 24 h. Total nitrogen was determined by the Kjeldahl method. After mineralization of 5 g of CM, distillation and titration were done with a Buschi 342 apparatus coupled with an automatic titration apparatus (Dosimat E535-Titrator E526 METROM).

For free amino-acid quantification, the water-soluble fraction of CM was extracted. Ten g of frozen CM were grated and homogenized in 60 ml of water. The mixture was stirred at 40°C for 1 h and centrifuged at 2 000 *g* at 4°C for 30 min. The supernatant was adjusted to pH 4.6 with 2 mol l^{-1} HCl and centrifuged at 30 000 *g* at 4°C for 30 min. The supernatant was freeze-dried and

Prewarm water and milk fat to 50°C

⇓

Mix milk powder and salt with prewarmed water

⇓

Add native calcium phosphocaseinate by 6 g aliquots and mix 3 s each time

⇓

Add prewarmed milk fat

⇓

Add glucono-δ-lactone to adjust the mixture to the required pH

⇓

Keep 2.5 h at 33°C

⇓

Add rennet and allow 1 h at 33°C

⇓

Store below 15°C until use (24 h)

Fig 1. Method of production of the cheese model.
Méthode de fabrication du fromage modèle.

the powder obtained was dissolved in 2 ml buffer used for high performance liquid chromatography (HPLC) analysis which was performed according to Dong *et al* (1985) with an ion exchange column Polyspher AANA (4.6 x 25 cm) (Merck) and postcolumn ninhydrin reaction.

For lactose and salt quantification, 20 g of grated cheese and 50 ml of 12.5% trichloroacetic acid were homogenized for 5 min, incubated at 70°C for 30 min and centrifuged at 2 000 *g* at 4°C. The cream was removed and the supernatant was filtered through a Büchner filter system. The volume of the filtrate was adjusted to 200 ml with pure water. Sodium, potassium and calcium concentrations were analysed with a flame ionisation spectrophotometer (Eppendorf, Hambourg, Germany). After neutralization with NaOH solution, lactose was quantified by an enzymatic method (Boehringer, Mannheim, Germany).

Total fatty material was extracted according to Folch *et al* (1957) from a 3 g cheese sample. The solvent was then removed using a centrifugal concentrator until constant weight.

Total fatty acids were analysed according to the method described by Wolf and Castera-Rossignol (1987).

The rheological measurement, made with a digital rheometer INRA-SERT (Cardenas-Caroti *et al*, 1985), was a uni-axial compression test at constant speed. A cylindrical plug (diameter 200 mm) was taken from the cheese model with a cork-borer. Sample height was adjusted to approximately 20 mm with a two-parallel-wires system. Samples were stored 1 h before testing at 15°C, which was the assay temperature. The compression test was performed at a relative deformation of 80% of the initial height. Force was measured with a 125 N load cell, as the resistance of the sample to deformation. Stress was calculated as the ratio of force to the initial area of the sample. Cauchy strain, defined as the change of height/initial height, was calculated. Data were represented using a "stress-strain" curve (fig 2). The modulus of deformability, calculated as the slope of the initial linear part of the curve, characterized the elastic properties of the product. Fracture properties were evaluated from the coordinates of the local maximum of the "stress-strain" curve, called fracture strain and fracture stress. Work to fracture was calculated as the area under the curve until the fracture point, and represents the energy needed to deform the product until this fracture point and to break the cheese structure.

Sensory evaluation

Experiments were conducted in an air-conditioned room (20 ± 1°C), under red light in separate booths.

Sensory properties of the cheese model

The panel consisted of 12 panellists from the staff trained to recognize cheese tastes and flavours. A preliminary step of the study was to choose descriptors. CM and 2 cheeses with neutral taste (cow Mozzarella and Saint Florentin) were tasted and the most frequently cited descriptors (saltiness, acidity, bitterness, total flavour, milky flavour) were selected. The panellists were asked to rank the 3 samples according to their intensity for each of the 5 descriptors. The mean of ranks was calculated according to Tomassone and Flanzy (1977).

All statistical analyses were performed with the Friedman test followed by a multiple comparison test as described by Tomassone and Flanzy (1977) using the software PSA (OP&P, Netherlands).

Applications

Preparations of the samples

The water-soluble extract of goat cheese was prepared according to Salles *et al* (1995) without precipitation at pH 4.6 and ultrafiltration steps. Eight g of freeze-dried powder was dissolved in 0.1% of SP70 in pure water and incorporated in 100 g of cheese model.

The volatile fraction was obtained by distillation of the water-soluble fraction under reduced pres-

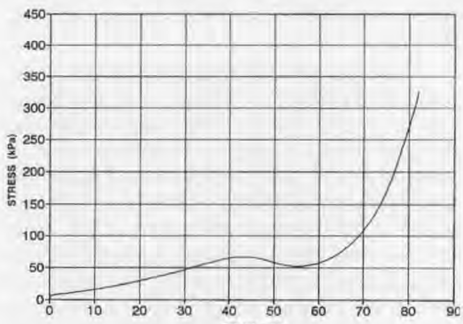

Fig 2. Rheological behaviour of the cheese model.
Comportement rhéologique du fromage modèle.

sure in a modified Forss and Holloway device (Forss and Holloway, 1967). The distillate (1.2 l per 100 g of cheese) was adjusted at pH 2 with 2 N HCl, added with 100 g l^{-1} of NaCl and extracted with dichloromethane. The dried organic phase was concentrated to 200 µl at 70°C with a Kuderna-Danish apparatus equipped with a Snyder column, and was incorporated directly in 100 g of cheese model. The residual dichloromethane content in the CM was quantified by a head-space technique and was found significantly lower (< 0.01 ppm) than the authorized level in food (Official Journal of the European Communities, 1988).

The quantities of pure compounds, determined in the goat cheese (unpublished results), and incorporated in the cheese model were as follows (in mg per 100 g):

– Ala (8.1), Arg (3.9), Asp (4.9), Cys (0.25), Cit (0.8), Gln (5.1), Glu (8.3), Gly (1.2), His (1.8), Ile (4.7), Leu (14.2), Lys (5.6), Met (2.9), Phe (8.5), Pro (6.1); Ser (7.0), Thr (4.7), Tyr (5.1), Val (7.1);

– NaCl (636), KCl (412), $CaCl_2$ (370);

– unbranched-chain fatty acids: C6:0 (20.7), C8:0 (33.8), C10:0 (8.5);

– branched-chain fatty acids: 4-methyl C8:0 (0.08), 4-ethyl C8:0 (0.009).

Sensory evaluations

Ten panellists were trained to recognize the basic tastes and the goat aroma. First, the panellists pinched their nostrils and put the sample (10 g) on their tongue to evaluate the taste; second, with open nostrils, they evaluated aroma. They were asked to classify each sample on a linear scale according to the intensity of its total taste and then its total aroma. Aroma and taste were described with free vocabulary after the evaluation of both total intensities. The statistical treatment of sensory evaluation data were monitored with SAS statistical software (SAS Institute, 1989) and programs developed in our laboratory. An analysis of variance and a Student–Newman–Keuls test ($P = 0.05$) were conducted for both total taste and aroma intensities.

RESULTS AND DISCUSSION

Processing of the cheese model

The nature and proportions of each component were chosen in order to make a CM with all required characteristics: low flavour intensity, no drainage, a cheese-like texture (hard paste) and easy incorporation of flavour compounds.

The preparation and properties of native phosphocaseinate are described by Pierre *et al* (1992). Its rennet coagulation time is 53% lower than raw milk; gel development kinetics and final firmness are increased by more than 50%. "Low heat" milk powder prepared by microfiltration of milk followed by drying has also improved rennet coagulation properties (Schuck *et al*, 1994), due mainly to the low temperature used throughout the drying process, which leads to a low denaturation rate of proteins.

Some milk creams and 1 sample of deodorized MF were tasted to choose the fat. Compared to the creams, which generally have a sweet taste and an intense milky aroma, deodorized MF was found to be tasteless and to have a very low aroma intensity. Moreover, its incorporation in the protein solution was straightforward.

Several types of apparatus were tested for mixing all the components of the CM. Among those tested – Ultraturrax® T25 (IKA-Labortechnick, Staufen, Germany), Kitchenaid® (Kitchenaid Inc, St Joseph, MI, USA) and Waring Blender® (Dynamics Corporation of America, New Hartford, CT, USA) – the latter, used at a low rotation speed, produced a CM with the best appearance: a hard, smooth paste. On the other hand, the Ultraturrax® produced a viscous mixture and a CM with a granular texture while the Kitchenaid® produced a CM with a frothy texture.

The principal problem was to adjust the pH of the CM. On the one hand, the use of bacteria was prohibited because it led to the production of aroma compounds, while, on the other hand, the addition of acids such as HCl, lactic or citric acids led to local precipitation of caseins before being mixed with the paste and consequently resulted in a CM of poor quality. The solution was found with glucono delta lactone (GDL), which hydrolyzed slowly in the mixture to form gluconic acid. Total acidification was achieved within 2.5 h after its incorporation. The percentage of GDL used was related to the pH through the formula:

$$\% \text{ GDL} = 1.28\ \Delta\text{pH} - 0.46$$

This equation has been determined with quantities of GDL from 0.4 to 1% (pH between 6.3 and 5.7), with a coefficient of correlation equal to 99.83 ($P < 0.01$, $df = 2$).

Exudation of the CM was measured by comparing the weight of thirty 50 g aliquots of CM after 1 and 2 d at 14°C. After 1 d, no drainage was observed and after 2 d, a quantity of water equivalent to only 5% of the cheese weight was lost (8.3% of total water contained in the CM). It was thus possible to prepare the cheese model the day before the evaluation test and store it at 4°C.

Physicochemical analysis

The physicochemical analyses of the CM are presented in table I. The CM was made by 3 different operators to test the reproducibility of the process. For each operator, 5 analyses were made to test the repeatability of all the physicochemical measures.

We chose to measure the parameters that seemed to us to be the most important concerning the physicochemical characteristics and the flavour of the CM.

For each parameter analysed, the coefficient of variation was generally less than 10%, except 2 values for potassium and calcium, indicating an acceptable repeatability for each operator. Concerning the comparisons between each operator, no significant difference was observed for each analysed parameter. This shows that the CM can be made easily by inexperienced operators.

All the values obtained for the CM were compared to mean values itemized by Feinberg *et al* (1987) for some typical kinds of cheeses (table II).

Dry matter and total N content

The dry matter content of the CM was around 40%, which was lower than the value observed for hard-paste cheese (around 60%) or soft-paste cheese (close to 50%). It was between the values for soft- and fresh-paste cheeses. It was found impossible to increase the dry matter content above 40% without harmful consequences for the final texture of the CM (very viscous paste, bad curdling, grainy texture) and a decreasing of rennet efficiency. A possible explanation could be the difficulty of hydrating the caseins sufficiently (Lorient *et al,* 1991).

This limitation led to a total N value lower than those observed for matured cheeses, but close to the values observed for salted cottage cheese or semi-dry goat cheeses (table II).

Fat in dry matter

The fat in dry matter content of the CM was close to that of a matured cheese (hard- or soft-paste). The fatty acid composition (in %; w/w) was as follows: C10:0, 5.9; C10:1, 0.5; C12:0, 6.8; C14:0, 17.5; C15:0, 1.5; C16:0, 33.1; C18:0, 8.3; C18:1, 17.2; C18:2, 1.3; C18:3, 0.3. This composition appeared similar to that of several cheeses (Feinberg *et al,* 1987).

Sodium

The sodium content was due mainly to the NaCl added. The sodium concentration was intentionally kept lower in the CM (690 mg kg^{-1}) than in most of the cheeses (between 2 and 3 g kg^{-1}) (table II). This will allow incorporation of flavour extracts containing salts (particularly water-soluble extracts) without any major consequences on the texture of the CM. Moreover, this low quantity of sodium added in the CM gave a softer paste than that obtained without the addition of NaCl.

Potassium and calcium

Potassium and calcium were present in concentrations close to those present in matured cheeses. Their origin was mainly MP and NCPP.

Table I. Physicochemical composition of the cheese model.
Composition physicochimique du fromage modèle.

Operator	*A*	*B*	*C*	F *value* *
Dry matter (%)				
Mean	40.2	40.3	39.5	0.8
SD	0.4	0.3	0.7	ns
CV (%)	1.0	0.9	1.6	
Lipids/dry matter (%)				
Mean	48.0	48.3	48.2	0.4
SD	0.6	0.4	0.7	ns
CV (%)	1.2	0.8	1.5	
Total N (g kg^{-1})				
Mean	23.4	22.8	23.8	0.06
SD	0.6	0.6	0.5	ns
CV (%)	2.4	2.6	2.1	
Sodium (mg kg^{-1})				
Mean	725.0	685.2	659.7	1.8
SD	75.5	49.9	23.9	ns
CV (%)	10.4	7.3	3.6	
Calcium (mg kg^{-1})				
Mean	5 246.4	5 492.1	5 582.1	2.3
SD	423.6	877.4	564.4	ns
CV (%)	8.1	16.0	10.1	
Potassium (mg kg^{-1})				
Mean	707.5	735.8	717.7	0.1
SD	156.1	50.2	16.8	ns
CV(%)	22.1	6.8	2.3	
Lactose (mg kg^{-1})				
Mean	18 904.0	18 270.0	17 646.0	1.6
SD	896.0	1 134.3	1 282.3	ns
CV (%)	4.7	6.2	7.3	

* *F* value of operator effect (*df* = 2,12). SD: standard deviation; CV: coefficient of variation; ns: not significant.
* *valeur* F *de l'effet opérateur* (df = *2,12). SD = écart type ; CV : coefficient de variation ; ns = non significatif.*

Table II. Comparison of the physicochemical composition between the cheese model and some typical cheeses (mean values).
Comparaison de la composition physicochimique entre le fromage modèle et des fromages typiques (valeurs moyennes).

	Dry matter (%)	*Lipid/dry matter (%)*	*Total N ($g\ kg^{-1}$)*	*Sodium ($mg\ kg^{-1}$)*	*Calcium ($mg\ kg^{-1}$)*	*Potassium ($mg\ kg^{-1}$)*	*Lactose ($mg\ kg^{-1}$)*
Cheese model	40	48.2	23.3	690	5 440.2	720.3	18 040
*Cow cheese**							
Comté	63.5	49.4	45.8	3 150	9 850	1 230	**
Emmental	62.3	46.5	46	2 210	11 970	1 030	2 000
Cheddar	64	52.3	40.8	7 000	7 400	1 000	
Edam	58.1	48.7	38.9	6 540	6 780	670	**
Camembert	46.1	48.1	33.3	8 020	4 000	1 100	
Pont l'Evêque	49.8	48.1	33	6 700	5 000	1 370	
Reblochon	49.3	51.9		8 700	6 400	2 000	
Cottage cheese (fresh)							
not salted	19.5	41	12.1	290	1 110		
salted	33.2	40.3	24.1	6 100	840		
*Goat cheese**							
Fresh	15.4	39.6	7.4	640	1 080		
Semi-dry	51.4	54.7	26.8	5 810	1 030		
Dry	69.4	56.7	43.2	7 900	1 900		

* Feinberg *et al*, 1987; ** near 0/*proche de 0*.

Lactose

The lactose content was quite high in CM (18 040 mg kg^{-1}), while it was absent from other cheeses due to fermentation by lactic bacteria. This high concentration was due to the addition of MP which contained 53 g of lactose for 100 g of dry matter. However, this MP was important in the CM composition because a CM made only with NCPP as source of proteins resulted in a cheese which was too firm.

Free amino acids

No free amino acids were detected in the CM, as expected, because no proteolysis occurred.

Rheological analysis

Table III gives the rheological parameters measured on the cheese model sample prepared by the different operators. The variability observed had usual levels. Significant, but low, differences between cheese models A, B, C for the modulus of deformability and the fracture strain were observed while no such difference appeared for chemical parameters. This result suggested a possible, but small, operator effect. It is noticeable that the cheese model had a "stress-strain" curve with a profile similar to hard cheese (Noël, personal communication), but the values of rheological parameters were much lower. The cheese model structure could have a cohesion similar to hard cheese but with a softer consistency. This must be confirmed by further investigations, however.

Sensory evaluation

The results of the sensory evaluation are presented in table IV. The CM was less salty and acid than the 2 cheeses. The differences were significant (P = 5%). The low saltiness was probably due to the low quantity of NaCl incorporated in the CM, and the low acidity was probably due to the low quantity of organic acids such as the lactic and propionic acids present.

The bitterness of the CM was similar to that of cow Mozzarella, but lower than that of Saint Florentin (P = 5%). The absence of proteolysis in the CM, and thus the absence of bitter peptides and free amino acids, could explain the lower bitterness.

The high concentration of lactose in the CM, compared to the very low concentration in typical cheeses (table II), did not seem to influence the taste because sweetness was not mentioned by the panel. Moreover, its mean concentration in CM (53 mmol kg^{-1}) was lower than the detection threshold of lactose in water, which is 72 mmol l^{-1} (Stahl, 1973).

Table III. Rheological properties of the cheese model.
Propriétés rhéologiques du fromage modèle.

Operator	*A*	*B*	*C*	F *value**
Modulus of deformability (kPa)				
Mean	83.2	97.8	97.2	4.7
SD	4.7	7.0	9.1	**
CV (%)	5.7	7.2	9.3	
Fracture stress (kPa)				
Mean	70.7	71.1	63.8	3.3
SD	7.5	3.7	2.6	ns
CV (%)	5.3	5.2	4.0	
Fracture strain (%)				
Mean	44.5	42.7	41.8	4.3
SD	1.9	0.6	1.6	**
CV (%)	4.3	1.4	3.9	
Fracture work (kJ k)				
Mean	12.9	14.3	13.5	1.6
SD	1.9	0.8	0.7	ns
CV (%)	14.5	5.5	5.3	

* *F* value of the operator effect (*df* = 2,12); ** significantly different at $P < 0.05$. SD: standard deviation; CV: coefficient of variation; ns: not significant.

* *Valeur* F *de l'effet opérateur* (df *= 2,12) ; ** différence significative à* P *< 0,05. SD : écart type ; CV : coefficient de variation ; ns : non significatif.*

The CM had the same total flavour intensity as cow Mozzarella, but it was significantly lower than that of Saint Florentin (5%). No significant difference was found between the 3 products concerning milky flavour. However, the CM obtained the lowest rank for 8 of 12 panellists. This aroma was linked to the milk powder and the phosphocaseinates and was difficult to eliminate.

Table IV. Comparison of some organoleptic properties between the cheese model and 2 low flavour cheeses.
Comparaison de propriétés organoleptiques entre le fromage modèle et 2 fromages peu aromatiques.

Cheese	*Rank* *			*Mean of ranks*
	1	*2*	*3*	
Salty				
Cheese model	10	2	0	1.17a
Mozzarella	1	4	7	2.50b
Saint Florentin	1	6	5	2.33b
	FR = 12.66; $P < 0.01$			
	significant difference at 1% = 1.19; at 5% = 0.96			
Acid				
Cheese model	7	5	0	1.42b
Mozzarella	5	7	0	1.58b
Saint Florentin	0	0	12	3.0a
	FR = 18.16; $P < 0.001$			
	significant difference at 1% = 1.19; at 5% = 0.96			
Bitter				
Cheese model	6	4	2	1.67a
Mozzarella	6	6	0	1.50a
Saint Florentin	0	2	10	2.83b
	FR = 12.67; $P < 0.01$			
	significant difference at 1% = 1.19; at 5% = 0.96			
Total flavour				
Cheese model	5	7	0	1.58b
Mozzarella	7	5	0	1.42b
Saint Florentin	0	0	12	3.0a
	FR = 18.16; $P < 0.001$			
	significant difference at 1% = 1.19; at 5% = 0.96			
Milky flavour				
Cheese model	8	1	3	1.58
Mozzarella	4	4	4	2.0
Saint Florentin	0	7	5	2.42
	FR = 4.17; ns			

The means assigned to the same letter (a, b) are not significantly different at the level of 5%. * Rank 1 : lowest intensity; ns : not significant.
*Les moyennes affectées de la même lettre (a, b) ne sont pas significativement différentes au seuil de 5%. * rang 1 : intensité la plus faible ; ns : non significatif.*

Examples of incorporation

General considerations

The incorporation of substances in the CM, such as pure aroma compounds or aroma extracts, could be made in MF during the process. Concerning more polar compounds, we tried to incorporate pure amino acids, respectively (in mg g^{-1} of CM): L-leucine (17.8), L-isoleucine (9.7), L-glutamic acid (31) and monosodium L-glutamate (31). These compounds were dissolved in 20% of the hot water used in the process and then incorporated before the addition of MF. For the incorporation of sodium salts, it was necessary to reduce the equivalent quantity of NaCl in the process to avoid large changes in the texture of the CM. Moreover, for the same reason, it was necessary to adjust the pH of the solution of amino acids or hydrosoluble fractions at 6.8 (pH of the paste at this step of the procedure) with NaOH solution before acidification with GDL.

Application to goat cheese

The results of sensory evaluations are reported in figure 3 for taste and figure 4 for aroma.

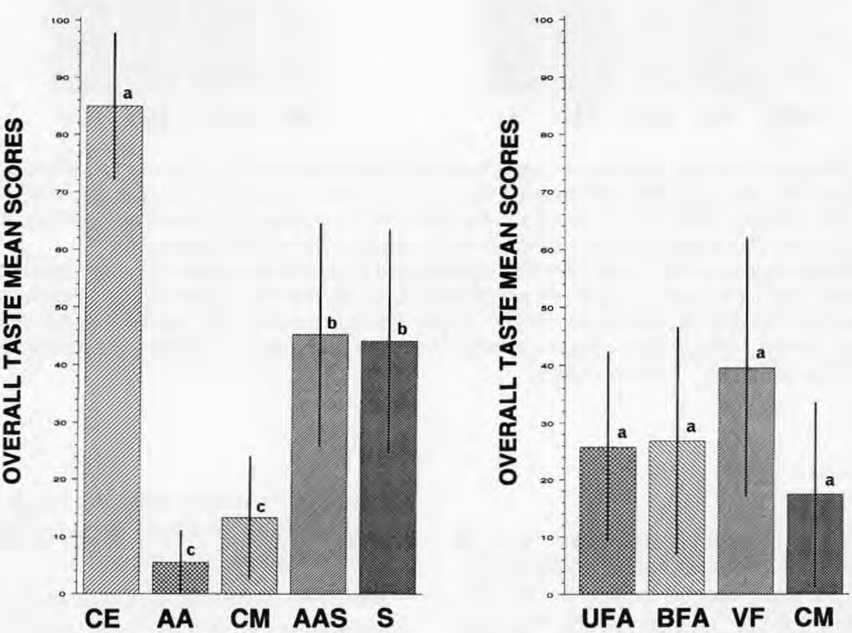

Fig 3. Overall taste mean scores of the reincorporations in the cheese model. The means with the same letter (abc) are not significantly different at the level of 5%. The confidence interval is drawn for each mean. CM: cheese model; CE: crude extract; AA: amino acids; S: salts; AAS: amino acids + salts; UFA: unbranched-chain fatty acids; BFA: branched-chain fatty acids; VF: volatile fraction.

Intensité moyenne de la saveur globale des réincorporations dans le fromage modèle. Les moyennes affectées de la même lettre (abc) ne sont pas significativement différentes à un seuil de 5%. L'intervalle de confiance est représenté pour chaque moyenne. CM : fromage modèle ; CE : extrait brut ; AA : acides aminés ; S : sels ; AAS : acides aminés + sels ; UFA : acides gras à chaîne linéaire ; BFA : acides gras à chaîne ramifiée ; VF : fraction volatile.

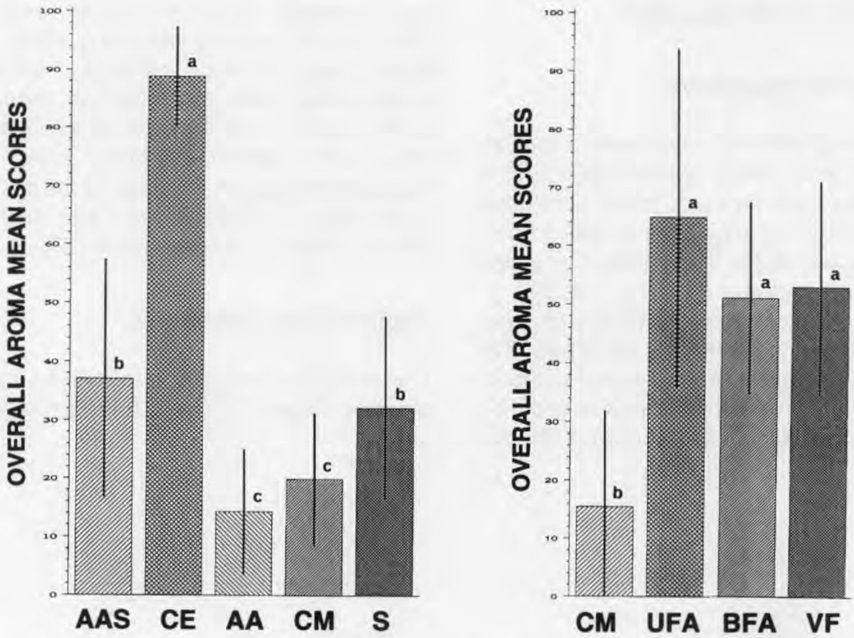

Fig 4. Overall aroma mean scores of the reincorporations in the cheese model. The means with the same letter (abc) are not significantly different at the level of 5%. The confidence interval is drawn for each mean. CM: cheese model; CE: crude extract; AA: amino acids; S: salts; AAS: amino acids + salts; UFA: unbranched-chain fatty acids; BFA: branched-chain fatty acids; VF: volatile fraction.
Intensité moyenne de l'arôme global des réincorporations dans le fromage modèle. Les moyennes affectées de la même lettre (abc) ne sont pas significativement différentes à un seuil de 5%. L'intervalle de confiance est représenté pour chaque moyenne. CM : fromage modèle ; CE : extrait brut ; AA : acides aminés ; S : sels ; AAS : acides aminés + sels ; UFA : acides gras à chaîne linéaire ; BFA : acides gras à chaîne ramifiée ; VF : fraction volatile.

Taste

The CM containing the crude hydrosoluble fraction of goat cheese had significantly (P = 0.05) the most intense taste. This sample was described as particularly salty. This was probably due to the high quantity of salt present in this extract. Concerning the CM (reference sample), the total taste intensity was low.

The amino acids, branched- or unbranched-chain fatty acid incorporations did not lead to a total taste intensity significantly different compared to the reference sample. For the amino acids, this result can be explained by their low concentration in this kind of cheese (ca. mg kg^{-1}).

Moreover, the addition of salts in the CM increased significantly the total taste intensity, but under the level obtained by the crude extract. The adjunction of amino acids to the salts had no effect. The difference of taste intensity between the crude extract and salts incorporated in the CM was probably due to other compounds or associations of compounds present in the crude extract.

Aroma

As for taste, the crude hydrosoluble fraction had the highest total aroma intensity. The most frequently quoted descriptor was "goat" then "cheese". The CM without incorporation had a low total aroma intensity.

The adjunction of free amino acids did not produce a significant effect. On the other hand, the adjunction of salts increased slightly but significantly the total intensity. This can be explained by a displacement of the residual aroma equilibrium in the CM because they are noted identically (whey, cardboard).

The incorporation of branched- or unbranched-chain fatty acids, or the volatile fraction leads to an important increase of the total intensity compared to the CM, but the total intensity of these 3 samples are not significantly different.

The samples containing the branched-chain fatty acids was noted "goat" by 8 panellists *versus* 4 panellists for the unbranched-chain fatty acids (by a total of 10 panellists). This result confirms that the 4-methyl and 4-ethyl octanoic acids are responsible for the typical goat aroma, as previously suggested by Ha and Lindsay (1991).

CONCLUSION

The preparation of this cheese model is easy, reproducible and repeatable. The intensity of its flavour was very low; it has a low taste intensity and showed only a slight milky flavour. It is edible if it is made with the usual sanitary precautions used in the dairy industry. The dry matter values and the rheological behaviour study showed that this model is more suitable for work on soft cheeses than on hard varieties.

This kind of cheese model would allow sensory evaluations to determine the impact of some cheese flavour and taste and to obtain more reliable results than if these evaluations were made with water. It will be interesting, for example, to test incorporation of flavour fractions of cheeses obtained by chromatography of the water-soluble fraction (Salles *et al*, 1995) and to evaluate their effective sensorial impact in cheeses. Threshold measurements of individual flavour compounds found in cheese could also be determined in a more precise way, using this bland cheese-like matrix.

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