Taste Active Compounds in a Goat Cheese Water-Soluble Extract. 2. Determination of the Relative Impact of Water-Soluble Extract Components on Its Taste Using Omission Tests

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The aim of this work was to determine the relative impact of water-soluble compounds on the gustatory properties of a goat cheese water-soluble extract (WSE). Using a semisynthetic model mixture (MWSE) previously elaborated in physicochemical and gustatory accordance with the cheese WSE (see part 1, Engel et al. *J. Agric. Food Chem.* **2000**, *48*, 4252−4259), omission tests were performed. Among the main taste characteristics of the WSE (salty, sour, and bitter), saltiness was explained by an additive contribution of sodium, potassium, calcium, and magnesium cations, whereas sourness was mainly due to a synergistic effect involving sodium chloride, phosphates, and lactic acid and bitterness was found to result from calcium and magnesium chlorides, the impact of which was partially masked by sodium chloride. In contrast, amino acids, lactose, and peptides did not have any significant impact on WSE taste properties. To quantify the contribution of the taste active compounds to bitterness and saltiness, stepwise multiple linear regressions were performed. Those contributions were expressed as a percentage of the considered taste characteristic intensity in the WSE. The model obtained allowed up to 97.4% of the perceived saltiness to be described and ~85% of the bitterness.

Keywords: *Omission tests; goat cheese; taste; synergistic effect; masking effect; peptides; minerals*

INTRODUCTION

As confirmed in part 1 of this series of two papers (Engel et al., 2000), the water-soluble compounds have a predominant role in cheese taste. The previous study permitted the reconstitution of a goat cheese water-soluble extract (WSE) taste by elaborating a semisynthetic model mixture (MWSE) in physicochemical and gustatory accordance with the WSE. The sensory validation of the model mixture implied that all of the water-soluble taste active components were correctly quantified in the extract and that they are all present in the MWSE.

Among the components of WSE, mineral salts, lactic acid, and amino acids are potentially taste active as has been shown by several authors (Biede and Hammond, 1979; Aston and Creamer, 1986; Salles et al., 1995b; Warmke et al., 1996). In contrast, the relative impact of some other chemical species such as peptides has not been clearly elucidated yet. If large water-soluble peptides are considered as bitter or tasteless (Visser, 1977; Lemieux and Simard, 1992), low molecular weight peptides (MW < 1000 Da) are considered to have an important taste impact (MacGugan et al., 1979; McSweeney, 1997), but until now, apart from bitterness, no clear demonstration of their actual sensory impact exists. Only a few small peptides were isolated from the water-soluble fraction of cheeses such as Vacherin Mont d'Or (Mojarro-Guerra et al., 1991) and Comté (Roudot-Algaron et al., 1994) by different chromatographic methods and identified (Roudot-Algaron et al., 1993). However, no direct correlations between these peptides and the organoleptic properties of the fraction, apart from bitterness, have been demonstrated.

To clarify the relative impact of each WSE component, new approaches have to be developed. A method to study the relative impact of molecules in mixture was tested by Fujimura et al. (1995, 1996). Starting with a model mixture representing a chicken meat extract taste, they measured the sensory effect of omitting one component of the solution on its taste profile. This technique, named the omission test, used by some other authors (Warmke et al., 1996; Sommerer et al., 1998) to study cheese taste, permits one to overcome interpretation problems inherent to correlation approaches such as, the inability to prove a causative linkage between physicochemical and sensory data (Williams, 1994). Particularly, omission tests allow for the determination of the particular impact of individual components in the mixture context without any "a priori" expectation or without assuming extrapolations based on their perception thresholds and qualitative properties measured in simple solution. Moreover, complex relationships such as synergistic or masking effects between compounds can be raised, thus permitting a full explanation of the taste of the food extract studied. As every mixture component is likely to have a role in its taste (Stevens, 1997), it is necessary to perform omission tests on a physicochemically and sensorially validated model mixture to be able to positively conclude at the original extract or product level. In the case of the goat cheese studied, using omission tests, Sommerer et al. (1998) showed that peptides isolated in the 500 Da nanofiltration retentate from an ultrafiltered goat cheese WSE do not have any significant impact on its taste profile.

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Table 1. Model Mixture Composition

Model Mixture Composition (g/L)

	mineral salts								lactic acid			peptides		
	NaCl	KCl	$CaCl_2$	$MgCl_2$	Na_2HPO_4	NaH_2PO_4	NaOH	lactose	lactic acid	NaOH	amino acids	RUF10	RUF1	RNF
MWSE	5.40	2.82	2.15	0.33	1.30	1.10	0.00	3.74	2.79	0.50	0.32	6.12	0.44	1.10
MWSEP	6.30	3.59	3.53	0.57	2.55	2.15	0.22	14.52	4.02	0.34	0.7	0	0	0

Amino Acid Composition (mg/L)

	Asp	Thr	Ser	Asn	Glu	Gln	Pro	Gly	Ala	Cit	Val	Cys	Met	Ile	Leu	Tyr	Phe	GABA	His	Orn	Lys	Arg
MWSE	4.9	5.3	14.6	11.3	10.4	23.1	28.0	2.3	17.0	0.6	14.2	3.1	2.7	6.7	50.7	19.8	31.5	27.8	0.0	6.2	16.4	21.9
MWSEP	14.8	13.3	30.0	25.1	22.4	52.1	58.6	4.7	33.1	16.1	37.7	4.1	14.0	23.6	109.1	36.6	52.7	57.5	4.3	14.8	51.6	25.7

However, in this last study, the lack of physicochemical and sensory validation of the model mixture used did not allow conclusions at the WSE level to be made.

Starting with the validated MWSE, the aim of this study was to determine the relative impact of individual WSE components by means of omission tests and to evaluate quantitatively each potent contribution.

MATERIALS AND METHODS

Chemicals. All synthetic components used in this study were of food grade and were purchased from commercial suppliers according to part 1. Pure water was obtained from a Milli-Q system (Millipore, Bedford, MA).

Model Mixtures. *Complete Model Mixtures.* MWSE is the semisynthetic model mixture previously elaborated in physicochemical and gustatory accordance with the cheese WSE (Engel et al., 2000). MWSE was elaborated in physicochemical accordance with WSE, using on the one hand synthetic chemical compounds and, on the other hand, ultra- and nanofiltration retentates as sources of peptides. MWSEP is the synthetic model mixture obtained by omitting all peptides from the MWSE. The compositions of both MWSE and MWSEP are given in Table 1. They were determined through the physicochemical assessment of a crude goat cheese WSE obtained after pure water extraction (see part 1) of a $2^1/_2$ week semihard goat cheese called "bouton de culotte" (Lycée Agricole de Davayé, Mâcon, France). In the case of the MWSE preparation, 10000, 1000, and 500 Da retentates were respectively obtained after successive 10000 and 1000 Da molecular weight cutoff membrane tangential ultrafiltration and 500 Da molecular weight cutoff membrane tangential nanofiltration of the WSE as extensively described in part 1.

Incomplete Model Mixtures. The incomplete model mixtures were prepared without adding the compounds in question to the synthetic solutions. With respect to the pH 4.6 of the WSE, NaOH was used to adjust the pH of complete model mixture (see part 1). In the case of the omission of compounds playing a role on the pH value of the mixture, meaning mainly phosphates and lactic acid, the following rules were applied. Part of the NaOH added permitted for the exact adjustment of the Na concentration of the MWSE to the same level as in the crude WSE. Thus, when phosphate or mineral salts were omitted, this part of the added NaOH was omitted too. However, to adjust the pH to 4.6, it was necessary to overcome the mineral physicochemical assessment and to add Na^+ in excess. This last part of NaOH was omitted only when lactic acid was not added.

Peptide Omission. Due to the remaining amount of compounds other than peptides present in the retentates, it was impossible to completely omit those compounds from the MWSE. Consequently, to compare the effect of lactic acid or mineral omission between MWSE and MWSEP, the same amounts of lactic acid and minerals were omitted.

Sensory Analysis. *General Conditions.* The evaluations were conducted under red light in an air-conditioned room (21 ± 1 °C). The room was equipped with 16 separate booths. To suppress olfactory sensations, the panelists' nostrils were pinched. At each measuring session, products were presented in a monadic way, according to a Williams Latin square design (MacFie et al., 1989) to balance report and position effects. Data were recorded with a FIZZ computerized system release 1.20 (Biosystemes, Couternon, France).

Training of the Panelists. The panel consisted of 16 students in the Master's of Sensory Sciences program at the University of Burgundy (ENSBANA., Dijon, France). Panelists were trained during 18 1-h sessions to recognize and quantify each basic taste, astringency, and sharpness in simple solutions or in complex mixtures. For each gustatory sensation studied, an appropriate reference solution was chosen. During the training sessions, the concentration of each reference chosen was adjusted in accordance with its intensity in the WSE or its purified fractions. The quantification of each attribute intensity was evaluated in comparison with the perceived intensity of the corresponding reference solution adjusted to a given concentration: lactic acid (sourness), 1.38 g/L; L-leucine (bitterness), 8 g/L; sodium chloride (saltiness), 4.5 g/L; L-monosodium glutamate (umami note), 0.6 g/L; D-lactose (sweetness), 23.75 g/L; potassium alum (astringency), 0.33 g/L; capsaicin (sharpness), 0.15 mg/L.

Omission Tests. All of the omission tests were performed during five 1-h evaluation sessions. Four and half milliliters of each solution was presented twice to the panelists in 90 mL of coded plastic cups. The model mixtures were prepared 3 h before the session. All solutions were placed at 21 ± 1 °C 1 h before their evaluation. Prior to every other task, panelists were asked to taste each reference solution and to memorize its intensity corresponding, by mutual agreement with the panel, to 50% of its assessment scale. Afterward they had to taste each product and score the intensity of each attribute using a 13 cm unstructured linear scale anchored from "no sensation" to "strong" per descriptor. A mark at the middle of the scale corresponded for each descriptor to the intensity of the reference solution. Between samples, the assessors rinsed their mouths with bread crumbs and mineral water. During the tests, they could taste some reference solution to recall each gustatory sensation and its intensity. All solutions were evaluated twice during one session, according to two William Latin square designs. The total number of solutions varied between 12 and 20 for each session. For each session in which the complete solution was the MWSEP, taste intensity deviations from the model mixture were calculated for each gustatory property, each panelist, and each replication. They were obtained by subtracting, for a given sample and a given attribute, its perceived intensity to the intensity quoted for the MWSEP. Thus, a mean taste intensity deviation from the complete model mixture was processed for each incomplete solution.

Statistical Treatments. The data were processed with the SAS system release 6.12 (SAS Institute Inc., Cary, NC). ANOVA analyses were performed at the level $\alpha = 0.05$, according to the model attribute = product + subject + product × subject, with subject considered as a random effect. Means were compared with the Newman–Keuls multiple comparison test (Student *t* test). The CAP SAS macro (Schlich, 1997) was used to assess the panelists' performances. To quantify the relative impact of each compound on each attribute, stepwise multiple linear regressions were performed with proc REG with the stepwise option to select the variables.

RESULTS AND DISCUSSION

Panelists' Performances. Prior to any interpretation of the omission tests, it was necessary to check the reliability and validity of the sensory measurements, assessing panelists' performances with CAP SAS macro (Schlich, 1997). Briefly, this technique allows three main questions to be answered: Which attributes allowed differences to be made among the products? Which subject expressed significant differences among the products? Which subject was in disagreement with the others as to the way to quote the products? This method was applied to all of the data of all the omission mixtures and produced Table 2.

Concerning the attributes, only salty, sour, and bitter are, on average, quoted at an intensity level greater than 10/100 (*G* mean values). Moreover, four terms show significant differences among products: salty, sour, bitter, and, to a lesser extent, astringent, according to their respective Fisher values of the product effect of the ANOVA (*F* product on Table 2). The MANOVA (Fisher value of the product effect of the multivariate analysis of variance) for the whole panel shows three significant dimensions, which obviously seem to be related to the main discriminating attributes salty, sour, and bitter. Consequently, the following results will deal only with those three major tastes of the WSE. The other gustatory characteristics reach such a weak perceived intensity level (see *G* mean values) that it would be presumptuous to give any interpretation of their variations in response to omission.

Individual performances of the panelists show that all subjects were able to discriminate among products for at least three attributes. According to the MANOVA, most of them have used more than three significant dimensions and show an important *F* value, thus indicating their ability to clearly differentiate the solutions. For example, subject 11, the least discriminating, could see only one dimension of difference among the mixtures studied, whereas subject 5 used three dimensions and was able to separate the products to a large extent.

Peptide Omissions. As the MWSE was made with both retentate and synthetic compounds (Engel et al., 2000), omissions concerning all of the compounds, apart from peptides, could be performed only on the synthetic part of the mixture. It implied that only part of each WSE component might be omitted due to their presence in the three retentates added. If peptides had shown an impact on the gustatory properties, it would have been necessary to purify them more efficiently.

As Figure 1 shows, no significant difference was found between MWSE and MWSEP, which means that those peptides found in WSE do not have any significant direct impact on the taste profile of the WSE and, consequently, on that of the cheese. Our data are in agreement with the results obtained by Sommerer et al. (1998) on another goat cheese sample.

However, peptides may have some indirect effect on cheese taste as suggested by numerous authors (Sommerer et al., 1998; Salles et al., 1995a; Roudot-Algaron, 1996). Some synergistic relationships could exist between peptides and some taste active compounds. For that reason, omissions of the synthetic part of probable taste active compounds such as mineral salts and lactic acid were carried out in the presence or absence of peptides. Apart from peptides, the extract has the same composition and the same pH as the MWSE. As Figure

Table 2. Panelist Performance—CAP Table

attribute[a]	*G* mean[b]	*F* product[c]	panelists[d] 5	1	10	14	13	9	4	2	8	3	6	7	15	12	16	11	*F* interact[e]
salty	47	43.3	9.5	10.5	−13	16.7	15.2	−22	5.59	−5.8	10.4	6.74	7.76	−2.7	5.26	12	−1.9	−4.9	2.17
sour	28	31.4	−5.7	20.1	20.9	2.51	4.1	2.8	−18	13	9.59	−5.9	5.14	−6.9	6.22	3.55	2	−2.1	1.95
bitter	24	9.32	−69	−8.4	−6.6	2.3	3.69	−5.3		2.99	2.41	−4.4	12.1	−3.3	5.17		−3.7		3.33
astringency	2.6	3.27	−1.7						2.2	1.84				3.39				−2.8	1.25
sharp	1.5			3.48								−2.1	2.95		2.54				
sweet	1.2				2.55					2.56	2.6	.	.	−2	.		−2.6	.	1.57
umami	0.99		−2	7.89	.			2.6				2.52	2.51	.		2.47			1.52
MANOVA[f]		12.6	14.6	6.84	6.42	5.46	4.67	4.48	4.26	4.06	3.91	3.77	3.71	3.6	3.46	2.58	2.11	1.71	1.89
NDIMSIG[g]		3	3	4	3	2	3	2	2	3	3	4	3	7	3	2	2	1	6

[a] Ranked according to *F* product. [b] Grand mean over all panelists and all replicates. [c] Fisher values of the product effect of the analysis of variance calculated in the model attribute = product + subject + product × subject, where subject is considered as a random effect. [d] Fisher values of the product effect of the individual analysis of variance of the model attribute = product. Only significant values are printed. Values preceded by a minus indicate disagreement with the panel about the ranking of the product. [e] Fisher value of the product × subject effect of the analysis of variance calculated as described for *c*. [f] Fisher values of the product effect of the multivariate analysis of variance calculated according to the model attribute = product + subject + product × subject. Subjects are ranked by decreasing order for this *F* value. [g] Number of significant dimensions of the MANOVA.

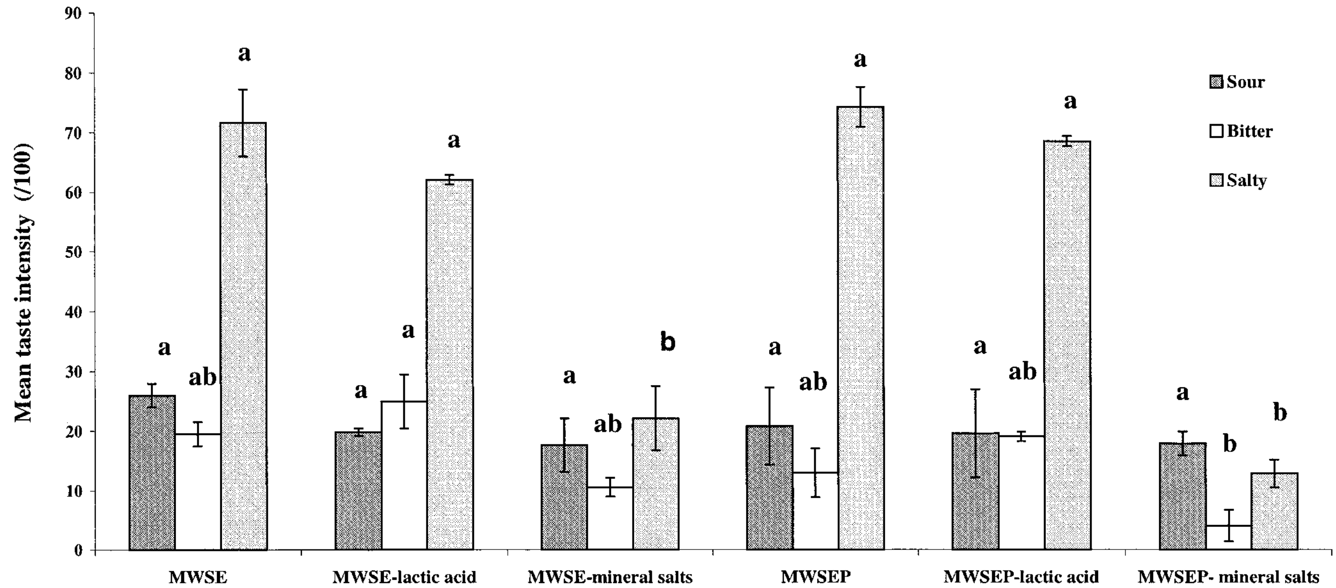

Figure 1. Omissions of mineral salts in the presence or absence of peptides. For each attribute, means with the same letter (a−d) are not significantly different at the level of 5% according to Newman−Keuls tests. The mean deviation is drawn for each mean. All omissions have been performed for two replicates.

1 attests, only mineral salts omission seems to have any impact on the taste profile of WSE, independent of the presence of peptides. Concerning lactic acid, its partial omission seems to decrease the sour note, but, with or without peptides, no significant effect may be concluded. As the total amount of peptides in the three retentates did not have any significant direct or indirect taste impact, it was not necessary to perform omission tests on each size class of peptides, as was initially planned, and therefore retentates were omitted for further tests, making it possible to carry out the complete omission of each compound participating in the composition of the MWSEP.

Omission of the Other Components. These were performed on the MWSEP. Figure 2 indicates for each omission taken into consideration the mean taste intensity deviation from the model mixture MWSEP for each of the three taste characteristics studied. Concerning amino acids and lactose omissions, no significant deviation from the MWSEP was observed, which means that they do not have any significant taste impact. In contrast, omissions of minerals and lactic acid were responsible for significant mean taste deviation. On the one hand, minerals seem to be responsible for the salty note as previously shown by Sommerer et al. (1998) and to partially decrease the sourness. On the other hand, lactic acid increases the intensity of the sourness.

Although Biede and Hammond (1979) found no correlation between lactic acid and the sour note, it is generally admitted that it may contribute to the cheese sourness because of its effect on pH (McSweeney, 1997). However, even if the impact of mineral salts is as salty compounds as claimed by several authors (McSweeney, 1997; Salles et al., 1995b; Sommerer et al., 1998), their relative impact on the sourness or bitterness has also to be detailed by their individual omission. To specify the relative contribution of the different mineral salts, omissions of NaCl, KCl, $CaCl_2$/$MgCl_2$, and phosphates were performed separately, and the results are shown in Figure 3.

As they caused a significant negative mean saltiness deviation when they were omitted (Figure 3), each of the four mineral salts contributes positively to the salty note in an additive way. Moreover, the results of the Newman−Keuls test indicate that the decrease of the mean saltiness deviation due to sodium chloride omission was greater than with other minerals taken one by one but weaker than when all of them were omitted. Thus, if sodium chloride appeared as having the biggest impact, the other salts might be necessary to explain the whole salty note. Although there is no agreement as to the mechanism of salt perception, it is admitted that cations are responsible for salty taste (Lynch, 1987; Laing and Jinks, 1996). According to this theory, the contribution of phosphates to the saltiness is probably due to the fact that they are added as sodium salts and each of the present mineral cations (Na^+, K^+, Ca^{2+}, and Mg^{2+}) may act in an additive way to explain the saltiness of the whole WSE.

Concerning sourness, phosphates have a decreasing effect because their omission caused a positive mean taste deviation as shown in Figure 3. On the contrary, sodium chloride has an enhancing influence. The effect of phosphates can mainly be related to their role on pH. Although there is evidence of the role of H_3O^+ concentration in the perceived level of sourness (Laing and Jinks, 1996), this taste characteristic has never been directly correlated with pH, which means that other compounds are probably involved in that perception. As evoked by Helleman (1992), sodium chloride may enhance the sourness of lactic acid in water and in wheat bread. This effect was confirmed in the case of the goat cheese WSE. Thus, sourness appeared to be due to an enhancing effect of sodium chloride on compounds acting on the pH level, phosphates and lactic acid. This conclusion was confirmed by the simultaneous omission of phosphates and sodium chloride, which led to a positive mean sourness deviation weaker than when phosphate was omitted alone (Figure 3). This means that the significant increase of the sourness due to phosphate omission is partially compensated by the omission of sodium chloride, which tends to decrease the sour note because of its enhancing contribution.

Figure 3 indicates that omission of both calcium and magnesium chlorides was responsible for a significant decrease of the bitter taste, which means that they

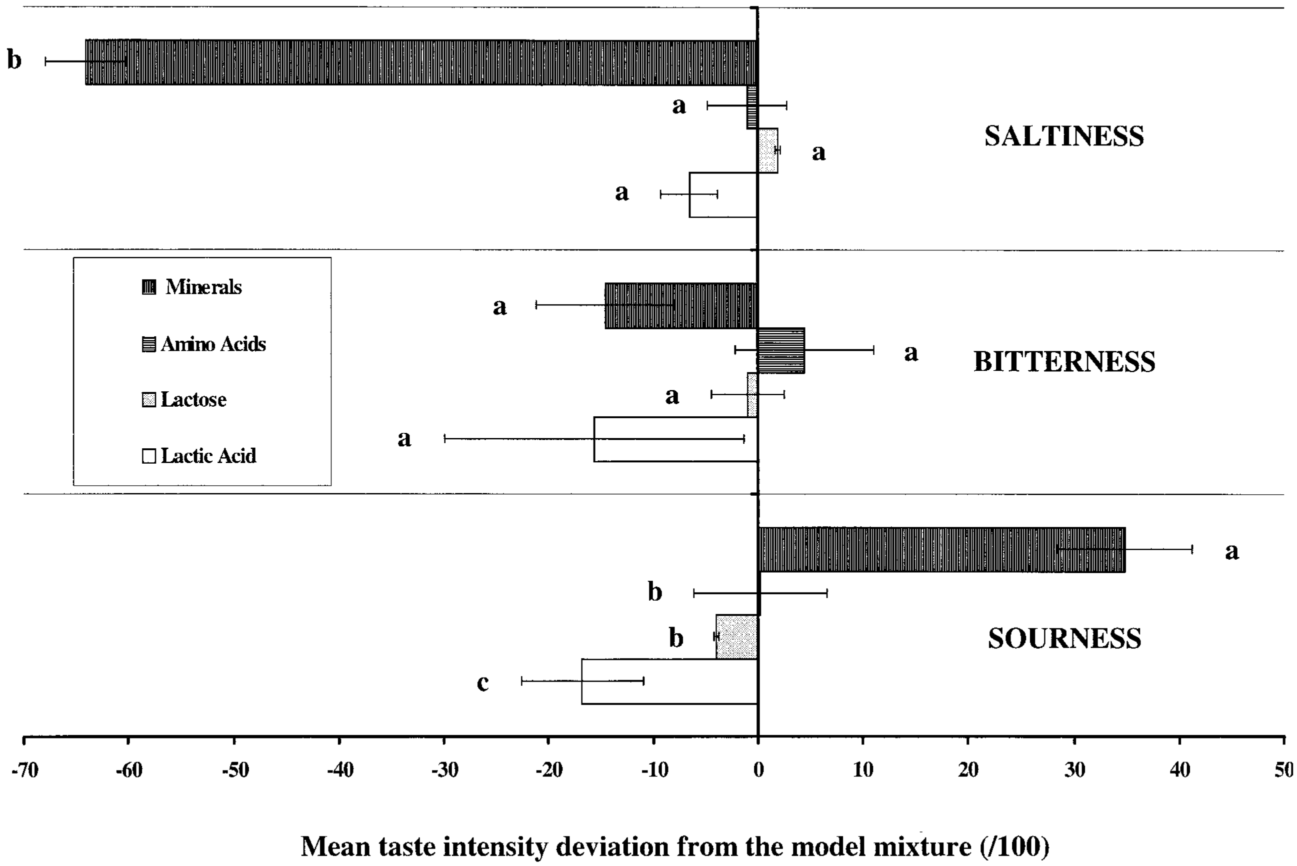

Figure 2. Omissions of lactose, amino acids, lactic acid, and mineral salts performed on the MWSEP. For each attribute, means with the same letter (a−c) are not significantly different at the level of 5% according to Newman−Keuls tests. The mean deviation is drawn for each mean. All omissions have been performed for two replicates except for minerals, which have been omitted for six replicates.

might be at least partially responsible for WSE bitterness. Some elements support that inference. As was previously shown by Tordoff (1996), calcium and magnesium are considered to be bitter/salty, and the taste of cheeses salted with $CaCl_2$ or $MgCl_2$ was extremely bitter after 16 weeks of ripening (McSweeney, 1997). In addition, the bitter taste of calcium is in accordance with the supposed bitterness perception mechanism at the receptor level described by Laing and Jinks (1996): bitter taste would be due to a series of reactions initiated by the binding of bitter stimuli to a receptor protein resulting in the opening of an ion channel allowing Ca^{2+} to flow into the cell. Thus, it is probable that ionic stimuli such as calcium cations may have the ability to interact directly with ion channels in taste receptor cell membranes. To evaluate the individual tastes of the divalent cations, a simple solution was prepared with calcium chloride and magnesium chloride at their concentrations in the MWSEP and submitted to the panel judgment for two replicates. Although the other taste characteristics were quoted as weaker than 7/100, the mean bitterness note was around 80/100 and improved the validity of the previous hypothesis. It can be concluded that calcium chloride and magnesium chloride are partially responsible for MWSEP bitterness. However, comparison between the level of bitterness reached in the simple solution (around 80/100) and in the MWSEP (around 30/100) indicates that some other constituents present in the MWSEP might act as repressors or partial masking agents of the bitter taste. This fact confirmed that it is impossible to consider only the individual taste properties of a compound to explain its impact on the WSE mixture context. Although it had no significant impact, the omission of sodium seems to have a tendency to increase the perceived bitterness. In addition, the simultaneous omission of phosphate and sodium chloride (see Figure 3) significantly increases the bitterness perceived, whereas the phosphate omission alone had no effect. The quantity of phosphate anions being the same in both cases, the increase of the perceived bitterness due to the simultaneous omission may be explained by a larger amount of sodium omitted, whereas when sodium phosphates were omitted alone, this sodium effect was too weak to be perceived. Thus, the masking effect of sodium chloride on the bitterness, mentioned by several authors (Breslin and Beauchamp, 1995; Stevens, 1997), may occur in the WSE and would partly explain the reduced level of bitter taste in the MWSEP in comparison with that reached by the simple solution of calcium chloride and magnesium chloride.

Quantification of the Contribution. To quantify the contribution of each compound of the MWSEP and consequently of the WSE, stepwise multiple linear regressions were processed on the omission tests data. The data set was presented as a contingency table in which each occurrence was an omitted solution and the variable was the presence (1) or the absence (0) of each of the omitted compounds. The results, shown in Table 3, indicate the parameter of the regression for bitter and salty tastes only. The sour data were not processed as each omission led to different H_3O^+ concentration values.

Concerning the saltiness, the total R^2 values attests that 97.4% of this taste property is explained. The

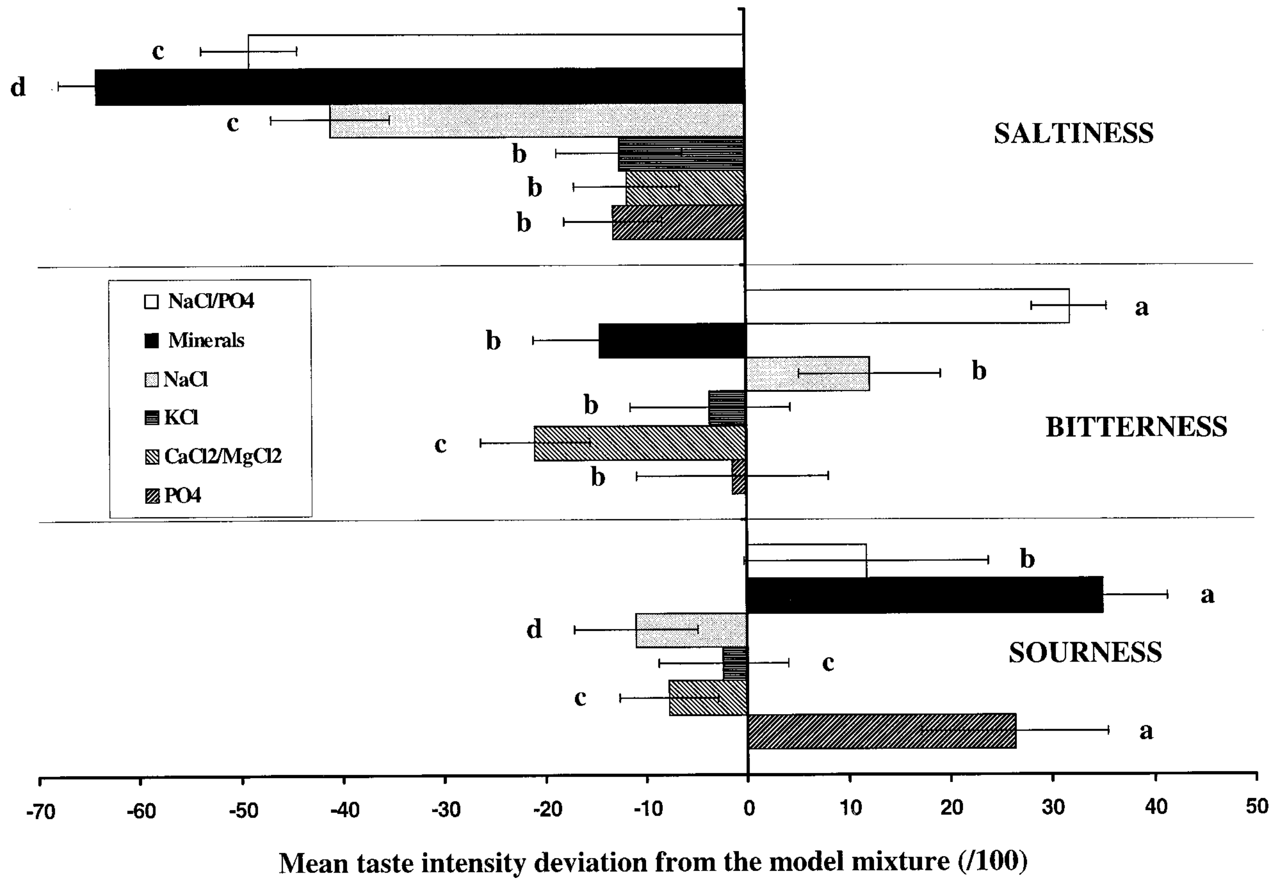

Figure 3. Individual omissions of mineral salts performed on the MWSEP. For each attribute, means with the same letter (a−d) are not significantly different at the level of 5% according to Newman−Keuls tests. The mean deviation is drawn for each mean. All omissions have been performed for six replicates.

Table 3. Quantification of Relative Contributions to WSE Taste

taste		NaCl	$CaCl_2/MgCl_2$	KCl	phosphates	lactic acid	total R^{2d}
saltiness	partial R^{2a}	75%	13.8%	5.8%	4.4%		**97.4%**
	α^b	0.01%	0.1%	0.25%	0.35%		
	contribution[c]	+	+	+	+		
bitterness	partial R^{2a}	29.2%	41.3%		9.4%	4.4%	**84.3%**
	α^b	0.2%	0.5%		2.8%	9.2%	
	contribution[c]	−	+		−	(+)	

[a] Partial R^2 of the omitted component resulting of the stepwise multiple linear regression. [b] Type 1 risk related to the corresponding partial R^2 value. [c] Indicates the positive (+) or negative (−) impact on the intensity of the considered taste. [d] Total R^2 corresponding for a given taste to the total contribution quantified.

partial R^2 value indicates the percentage of this attribute explained by a given component being part of the model; NaCl, $CaCl_2/MgCl_2$, KCl, and phosphates are, respectively, responsible for 75, 13.8, 5.8, and 4.4% of the salty taste. The respective values of type 1 risks α associated with each of those partial R^2 values are weaker than 0.5% and indicate a correct level of confidence. For the reasons evoked above, the impact of phosphates is presumably due to the amount of sodium added with the phosphates, and the percentages mentioned for the chloride salts could, in fact, be related more to the cations than to their respective level of chloride counterions. All of these impacts are positively correlated to the intensity of the saltiness, confirming additive contributions.

As Table 3 shows, bitterness is mainly due to the antagonistic effects between $CaCl_2/MgCl_2$ (41.3%) for the positive contribution and both NaCl (29.2%) and sodium phosphates (9.4%) for the negative one. In the same way as for the saltiness, the impact of sodium phosphates might be essentially due to the sodium. In contrast with the relatively weak α values associated with the partial R^2 value of $CaCl_2/MgCl_2$, NaCl, and sodium phosphates, lactic acid is shown as contributing 4.4% of the bitter taste with a high risk (9.2%). This compound, which did not have a significant impact on bitterness according to a *t* test and Newman−Keuls analysis (see Figure 2), was introduced in the stepwise regression because of its tendency to decrease the intensity for this attribute. During the preparation of the model mixture, we noticed that when sodium phosphates and calcium chlorides were added, precipitation occurred in the solution when lactic acid was totally omitted. This precipitate was certainly due to aggregation of calcium and/or magnesium with phosphates, creating a chemical association weakly soluble at the relatively high pH due to the absence of lactic acid. Thus, the decreasing tendency of bitterness when lactic acid is omitted (see Figure 2) as well as its partial R^2 value (Table 3) is probably due to a decreasing amount of soluble calcium and magnesium cations. In the case of lactic acid omission in the presence of peptides, it was interesting to notice that no precipitation occurred, which implies that some peptides seemed to have an indirect role in avoiding precipitation. To give a chemical explanation to that phenomenon, further studies have to be carried out. However, apart from lactic acid to which 4.4% of bitterness could be related, >80% of this taste is explained by the partial masking effect of sodium chloride and phosphates on the direct taste of calcium and magnesium chlorides. The unexplained 15% could be due to residual contributions such as KCl or peptides, the respective concentrations of which were too weak as they were individually omitted. KCl shows a slight tendency to increase bitterness and is known in the literature for its bitterness (McSweeney, 1997), whereas peptides, the omission of which tends to decrease the bitter level (Figure 1), are often cited to be bitter (Lemieux and Simard, 1992; Habibi-Najafi and Lee, 1996; Roudot-Algaron, 1996).

Conclusion. Omission tests performed on the MWSE and MWSEP allowed for the relative impact of WSE components on their tastes to be specified, highlighting complex interactions between compounds: additive effects of salts on saltiness, enhancing effect of sodium chloride on sourness due to the balance between phosphate and lactate species in respect to pH value, and masking effect of sodium chloride on bitterness mainly due to calcium chloride and magnesium chloride. Thus, because interactions with taste have been proved to be fundamental, the methodology used in this study could be a good alternative to independent sensory assessment of WSE fractions obtained by different separation techniques (Salles et al., 1995b), which do not permit the determination of synergistic, masking, or additive impacts involving compounds mainly present in two separate fractions. Moreover, this approach allowed each of those contributions to be quantified in the mixture context without taking into account comparisons between compound concentration in the product and its perception threshold in simple solutions, often called taste activity value determination (Schlichterle-Cerny and Grosch, 1998; Warmke et al., 1996).

In the case of the goat cheese studied, mineral salts and lactic acid are the main taste active compounds, whereas lipids, the volatile fraction (Engel et al., 2000), lactose, amino acids, and peptides did not have any significant impact. More especially, calcium chloride and magnesium chloride have been shown to explain the bitter taste of the cheese. As the bitter taste of cheeses was more often related to the presence of bitter peptides, the relative impact of peptides, calcium chloride, and magnesium chloride on the gustatory property of another model cheese is now under investigation.

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