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Fat-salty sensory interactions in model cheeses: multivariate analysis of a compilation of data from different projects organised in the BaGaTeL database

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Abstract

The food industry needs to develop new strategies to formulate well-balanced products in terms of nutritional and environmental requirements and sensory acceptability by consumers. The BaGaTeL database has been built, guided by a process and observation ontology in food science, PO² ontology, to integrate data on dairy foods composition process, nutritional and sensory properties, using a consensual model and a shared structured vocabulary. We searched the database, using specific queries, for samples for which data of composition, rheological properties and sensory profile analysis were available. However, the composition and structure of the dairy products and the measured variables are often very different, which do not allow a direct comparison of the data. Thus, we made a selection of 68 model cheeses from 6 different projects made with different compositions (fat, protein, minerals, and water). A principal component analysis (PCA) performed on this set of samples revealed that the sensory hardness was better explained by a low moisture-in-non-fat-content than by a high protein content as was often suggested and that the intensity of salty taste was not only linked to salt content but was also modulated by cheese composition. Considering a subgroup of 22 samples from 3 projects, in which fat perception was also measured, a partial least square analysis revealed that fat perception was not only explained by fat content but was also highly influenced by salty taste, and that salty taste was more correlated with fat perception than with sodium ions content, highlighting sensory fat-salty interactions.

Keywords: database, dairy product, rheological properties, sensory analysis, statistical analyses.

Introduction

The food processing sector is facing sustainability challenges of growing complexity, such as climate change, increase of overweight, obesity or population aging. These problems make it necessary for the food industry to develop new strategies to formulate well-balanced products in terms of nutritional and environmental requirements and sensory acceptability by consumers. To tackle this challenge, the BaGaTeL database has been built, guided by a process and observation ontology in food science, PO² ontology [1]. BaGaTeL aims to integrate data in the field of reformulation of dairy products taking into account their nutritional and sensory properties, using a consensual model and a shared structured vocabulary. Our data organization allows gathering information from different projects performed on different samples more or less comparable. The aim of the present paper is to demonstrate that a common analysis of data obtained on samples from different projects could help to generalize the hypotheses from the initial projects and even find new relationships. We restricted our analyses to model hard cheeses as they represent 22% of the samples in BaGaTeL, and focused on the links between cheese composition, structure and sensory properties.

Experimental

Data from 65 different projects (693 samples) have been imported in BaGaTeL, with their associated metadata (project title, coordinator, abstract, references, material, method, unit, description) [2, 3]. In BaGaTeL, 488 samples have data on rheological properties, 524 have data on sensory description but only 252 samples have data on composition, rheological properties and sensory profile analysis. However, the food structures of these samples are very different, from yogurt to hard cheese and the rheological methods are different. We thus restricted our search to model hard cheeses, analysed by uniaxial compression and found 68 samples from six projects.

The statistical analyses (PCA and PLS) were performed with XLStat (Addinsoft, Paris, France). The whole set of data is available on the DataINRAE open access repository in the BaGaTeL dataverse [4]. The data are described

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(scatter plots) in Guichard et al. [5], with the correlation matrices for the different sets of samples (Table S1 for PCA, Table S6 for PLS).

Results and discussion

Principal component analysis (PCA) on the whole set of 68 samples

The composition in lipid, protein, NaCl and water of the samples in the different projects is given in Table 1.

Table 1: Short description of the samples from the six selected projects.

Project	Number of samples	Lipid content (g/kg)	Protein content (g/kg)	Added NaCl (g/kg)	Water (g/kg)	Melting salts (g/kg)	Ref.	pH
Adi	8	80 / 160	204 to 310	4.94 / 14.94	600	0	[6]	5 / 6.2
Boisard	6	200 to 280	170 to 240	0 / 10	454 to 467	6,2	[7]	6.67 / 6.85
Lawrence	18	74 to 176	236 to 375	5 to 15	537 to 616	0	[8]	6.2
Tarrega	8	160 to 240	240 to 320	10	479	0	[9]	5.4
PraSel	24	173 to 290	228 to 297	7 to 25	419 to 542	0	np	4.96 / 5.35
Phan	4	197 / 297	283	0	383 / 483	31,2	[10]	5.4

np: non published results (personal communication).

A principal component analysis (PCA) was done on the 68 cheeses and 11 variables: 5 from the initial composition extracted from BaGaTeL, water, lipid, protein, sodium ions content (Na^+), 2 rheological parameters, YM (Young's modulus) and FS (fracture stress) and 2 sensory descriptors, hard/firm and salty. In addition to the variables of composition used in the different projects, three variables were calculated: (i) MNFS (moisture-in-non-fat-substances) is a useful variable in cheese manufacturing, and accounts for the available water, (ii) Lipid/DM (dry matter) better represents the impact of lipids in the lipid/protein network and (iii) Na+/water is more relevant to represent the concentration in sodium ions available for the taste receptors. These variables were not taken into account in the initial projects.

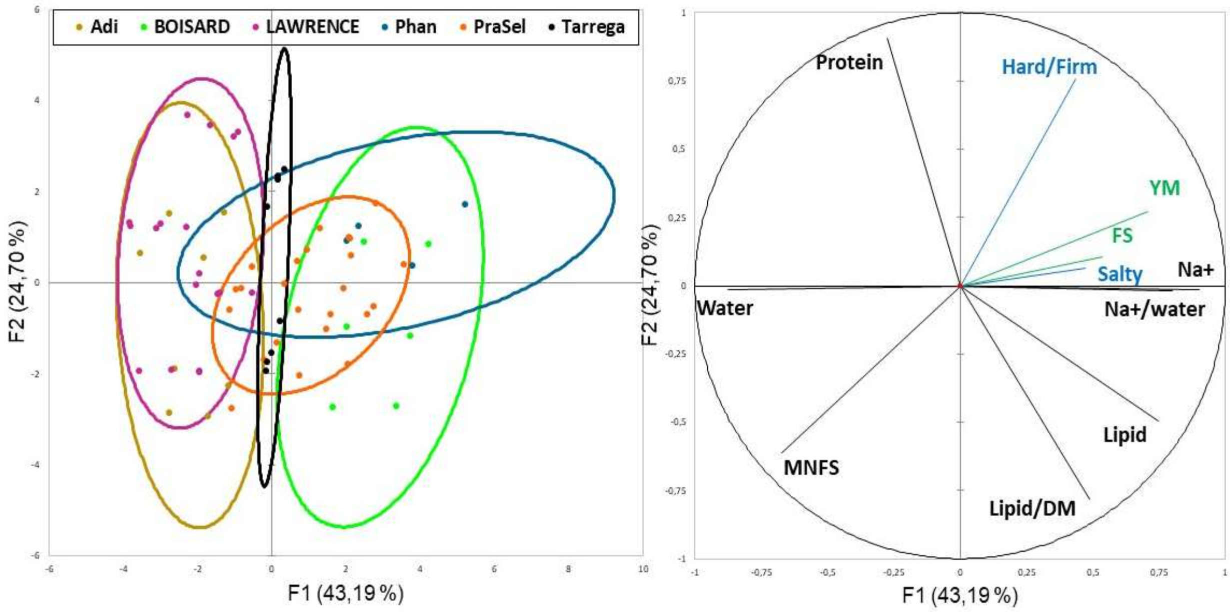

Figure 1: *Principal Component Analysis (PCA). Left: representation of the 68 cheese samples in the plane 1-2. Right: representation of the 11 variables in the plane 1-2.*

Figure 1 shows that there is a good overlap of the samples from the different projects in the principal plane (Axes 1-2), which accounts for 67. 9% of the information. The sensory descriptor hard/firm is explained by a high protein content (R2 = 0.542) and high YM (R2 = 0.629), as was also suggested in the initial projects, however the highest correlation (negative) is with MNFS (R2 = -0.723). The plot of hard/firm versus MNFS is shown in Figure 2.

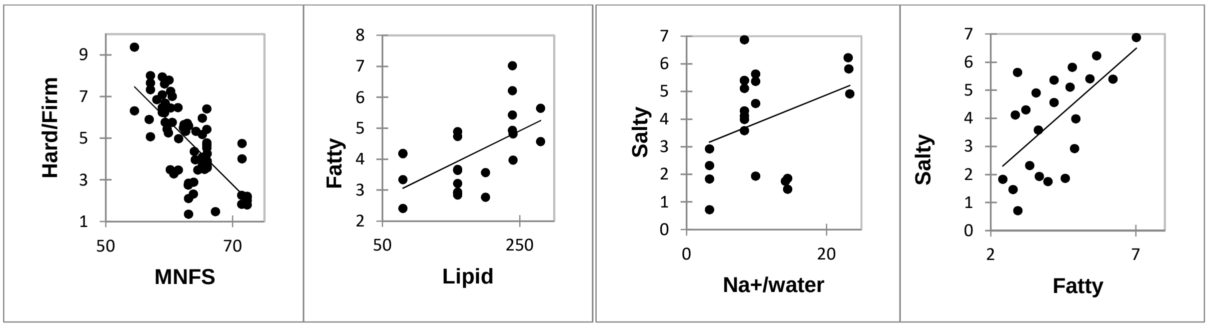

Figure 2: *Relationships between hard/firm and MNFS (R^2=-0.723) in the set of 68 samples; fatty and lipid (R^2=0.578), salty and Na+/water (R^2=0.348), salty and fatty (R^2=0.613) in the set of 22 samples.*

Our results confirm the impact of the protein network on sensory hardness but also emphasize the negative role of the amount of water in the non-fat phase. Our analysis also confirmed that salty taste was not only explained by Na+ and Na+/water, but also by the Young's modulus and fracture stress. This means that a more resistant cheese will favour the release of sodium ions in saliva and thus increase salty taste. In the individual projects, salty taste was influenced by the lipid content but the effects differed according to the projects. Phan et al., [10] found that salty taste was higher in cheeses with a low lipid content and Boisard et al., [7] found that salty taste was higher in cheeses with a higher lipid/protein ratio, which cannot allow to generalise the effect. Moreover, the impact of lipid, protein and water content was shown to vary according to the salt content, as detailed in Guichard et al., [11].

As some authors suggested the existence of sensory interactions between salty and fatty perception, we selected the samples in which fatty perception was measured, in order to test this hypothesis.

Partial least square (PLS) analysis on a subset of 22 samples

A partial least square (PLS) analysis was done on 22 cheeses with the sensory descriptor fatty, to explain the sensory perception (salty, fatty, hard/firm, crumbly, sticky, and springy) by data on composition and rheology.

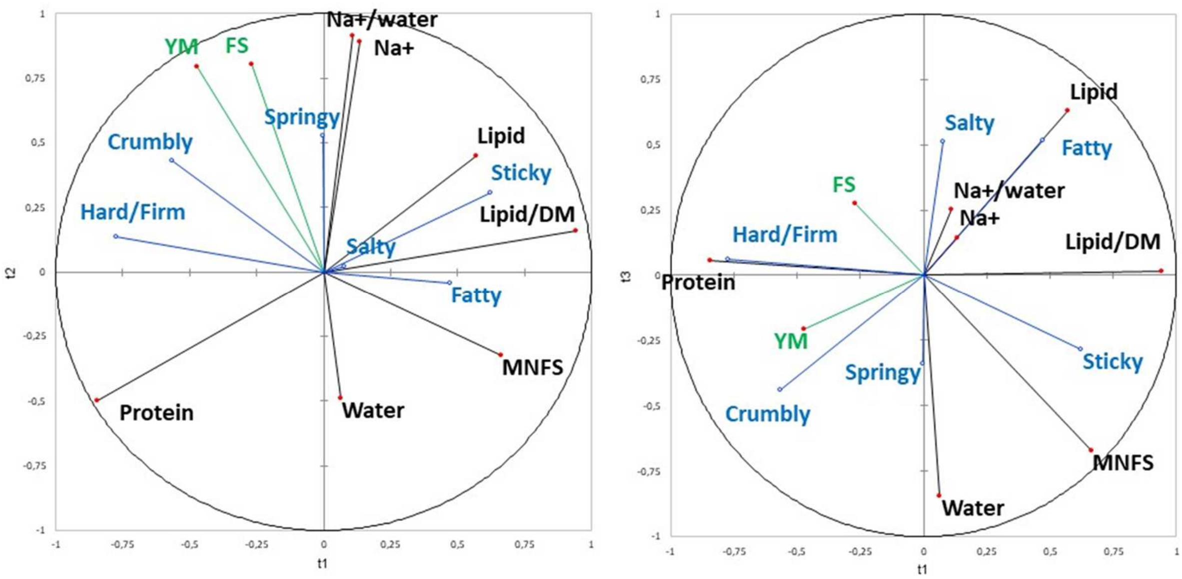

Figure 3: *Partial least square (PLS) analysis on 22 samples from Adi, Boisard and Tarrega projects. Left: representation of the variables in the plane 1-2. Right: representation of the variables in the plane 1-3.*

The representation on axes 1-2 and 1-3 (Figure 3) shows that the sensory hardness (hard/firm) is positively explained by the protein content (R^2=0.620) and negatively by the MNFS (R^2=-0.606), as already found in the PCA on 68 samples. A negative correlation was also found between hard/firm and lipid/DM (R^2=-0.607). Stickiness is better explained by the lipid/DM content (R^2=0.479) than by the lipid content (R^2=0.299), suggesting that it is more impacted by the lipid/protein network. Fatty perception is logically explained by the lipid content in the plane 1-3 (R^2=0.578), but the correlation is not very strong. In fact, fat perception is a multimodal perception involving olfactory, gustatory and tactile modalities [12]. However, salty taste is not as well explained neither by Na+ (R^2=0.358) nor by Na+/water (R^2=0.348). In the literature, the relationship between salty taste and cheese composition differs strongly depending on the projects, varying according to the salt content and also to the lipid content. The most interesting result is the strong correlation between salty and fatty taste (R^2=0.613), which suggests perceptual interactions between these perceptions in cheese. The plot of salty taste versus fatty taste supports this hypothesis (Figure 2). The impact of fatty perception on salty taste is higher for the highest values of fat perception.

Conclusion

BaGaTel database allows gathering with a same structuration, data obtained in different projects. It is thus possible to find relationships between different sets of data, composition, structure and quality, obtained on a wider range of foods, covering a variety of compositions.

This compilation of data from different projects allowed finding more general trends to explain sensory perception by cheese composition and rheological properties. The moisture-in-non-fat-substances variable was shown to be a relevant parameter to explain cheese sensory hardness. The contradictory results on the impact of lipid content on salty taste found in the literature could be explained by salty-fatty sensory interactions, suggesting that salty taste is more impacted by fatty perception than by sodium ions content and lipid composition.

Such a database is thus of tremendous support to uncover the mechanisms driving food perception but also to propose new formulations of well-balanced products in terms of nutritional and/or environmental requirements and sensory acceptability by consumers.

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