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Spectroscopic characterization of low- and non-fat cream cheeses

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ABSTRACT

Low-fat and non-fat cream cheeses were produced with variations in pH (4.4, 4.7, 5.0), salt concentration (0.4%, 0.65%, 0.9%) and fat content (0%, 3%, 6%, 9%). The cheeses were evaluated by four spectroscopic methods; fluorescence spectroscopy, near infrared spectroscopy (NIR), fourier transform infrared spectroscopy (FT-IR) and low-field nuclear magnetic resonance relaxometry (LF-NMR), to identify and describe the variation in cream cheeses induced by the experimental variables. The four methods complemented each other and gave somewhat different information about the products. Only LF-NMR was affected by all three design parameters and showed that high pH and high salt content made the low-fat samples resemble samples with higher fat content, with respect to water mobility. The sensory parameter, creaminess, could be predicted from the spectroscopic measurements, where NIR and FT-IR performed the best in the chemometric models. The spectra measured by these methods contained more information related to creaminess, but the use of a larger number of components indicated that the information was complex.

1. Introduction

There is an increasing demand for products with positive nutritional qualities, such as reduced fat or carbohydrate content. However, the products should retain the well-known sensory properties of the original products to achieve success in the market place (Martens, Frøst, & Martens, 2005). This introduces a challenge in the industrial development of low- or non-fat products. Fat influences both flavour and texture (Janhøj, Frøst, Prinz, & Ipsen, 2008; Wendin, Langton, Caous, & Hall, 2000) and serves as the main solvent for many aroma compounds, and marked reductions in fat content changes the aroma and flavour (Tepper & Kuang, 1996). Texturally, fat plays a role in acidified milk gels such as cream cheese by disturbing the acid gel (Frøst & Janhøj, 2007; Janhøj & Ipsen, 2006). It has been theorized that fat globules have a "ball-bearing" effect, whereby the fat globules rotate relative to each other during shear conditions in the mouth and this creates a fluidity of mass that attenuates the forces on the palate (Tolstoguzov, 2003).

Other compositional parameters influencing the appearance of cream cheese include protein, salt level and pH. For example, cream cheeses with low salt content and low pH were found to be grainier than those with higher salt content and higher pH (Janhøj et al., 2008). Wendin et al. (2000) also found that salt had a considerable influence on some flavour attributes and yellowness of the cream cheese. Furthermore, higher salt content gave larger fat droplets due to interactions between salt, proteins and fat (Wendin et al., 2000).

Creaminess is an important parameter in the evaluation of dairy products. In a number of dairy food categories, a high correlation between creaminess and fat content has been shown, e.g., in milk (Frøst, Dijkersterhuis, & Martens, 2001) and ice cream (Hyvönen, Linnea, Tourila, & Dijkersterhuis, 2003). Creaminess depends on other parameters besides fat content, since fat globule sizes, added fat mimetics, etc., are also important for texture (Frøst & Janhøj, 2007). Creaminess is a meta-descriptor, i.e., it is a compound property that is a result of a number of other properties. However, creaminess is also a multi-sensory experience that results from input through a number of senses: haptics, gustation, olfaction and expectations formed from appearance (Frøst & Janhøj, 2007).

In product development, it is important to obtain information about chemical/physical properties of the cheese as affected by changed processing conditions. It is crucial to find instrumental techniques that are able to capture small, but potentially important, variations in the sensory properties of the samples. Moreover, the measurements should be fast and non-destructive. Spectroscopic methods are often used for industrial quality control and are suitable both as screening methods during product development and as analytical methods within research. Spectroscopic data are commonly analyzed with chemometrics, as the use of basic chemometric models give a good overview of the often very complex data (Andersen, Andersen, Hansen, Skibsted, & Petersen, 2008; Salomonsen, Sejersen, Viereck, Ipsen, & Engelsen, 2007).

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In the study presented here, four spectroscopic methods were used; fluorescence spectroscopy, near infrared spectroscopy (NIR), fourier transform infrared spectroscopy (FT-IR) and low-field nuclear magnetic resonance relaxometry (LF-NMR). All four methods have shown abilities to describe various quality parameters of dairy products (Andersen & Mortensen, 2008; Bertram, Wiking, Nielsen, & Andersen, 2005; Curda & Kukackova, 2004; Karoui et al., 2006b,c; Karoui, Mouazen, Dufour, Schoonheydt, & de Baerdemaeker, 2006b; Salomonsen et al., 2007), but a thorough comparison of the analytical methods is still needed.

Therefore, the purpose of this work was to show how the four selected spectroscopic techniques, combined with multivariate data analysis, could be used to evaluate low- or non-fat cream cheeses with variation in fat, salt and pH, to non-destructively obtain information about chemical and physical changes within the samples and predict the creaminess. The advantages and disadvantages of each of the methods in this application are commented and discussed. Creaminess was chosen to be predicted from the spectroscopic methods to illustrate the suitability of describing consumer preference.

2. Materials and methods

2.1. Sample preparation

The cream cheeses were produced in a pilot plant at Arla Foods, Brabrand, Denmark as described by Janhøj et al. (2008). A homogenized and pasteurized milk base was fermented and treated according to a standard methodology. A $4 \times 2 \times 2$ full-factorial design with duplicate centre samples was applied, containing variations in fat content, salt content and pH (Table 1). This design was chosen to provide a wide sensory space. Fat was replaced by protein when making samples with different fat content. Thus, all samples had approximately the same water and dry matter content. Six replicates were obtained for each of the experimental conditions. The samples were taken from storage at 5 °C, tempered, stirred before sampling, and measured at room temperature (23 °C).

2.2. Fluorescence spectroscopy

The samples were measured on a Perkin Elmer LS50 B spectrofluorometer equipped with a Front-Face Accessory (Beaconsfield, Buckinghamshire, UK). A circular sample holder with a diameter of approximately 4 cm was used. For every sample, one excitation-emission matrix (EEM) was measured with excitation at every 10 nm from 260 nm to 360 nm. The emission spectra ranged from 260 nm to 600 nm. The slit widths were set to 7 nm for both excitation and emission and a 1% attenuation filter was used. Each measurement started with the highest excitation wavelength and ended with the lowest, to minimize photodecomposition of the sample. The scan speed was set to 1500 nm s^{-1}.

Table 1
Sample codes and experimental design.

Sample code	Fat content (%)	Salt content (%)	pH value
A	0	0.4	4.4
B	0	0.4	5.0
C	0	0.9	4.4
D	0	0.9	5.0
E	3	0.4	4.4
F	3	0.4	5.0
G	3	0.9	4.4
H	3	0.9	5.0
I	6	0.4	4.4
J	6	0.4	5.0
K	6	0.9	4.4
L	6	0.9	5.0
M	9	0.4	4.4
N	9	0.4	5.0
O	9	0.9	4.4
P	9	0.9	5.0
Q	0	0.65	4.7
R	0	0.65	4.7
S	9	0.65	4.7
T	9	0.65	4.7

2.3. Near-infrared spectroscopy

Visual/NIR reflectance spectra (400–2500 nm) were recorded on a NIR-Systems 6500 spectrophotometer (FOSS NIR Systems, Inc., Silver Spring, MD, USA). The measurements were obtained as the average of 32 scans using a spinning module (NR-6506). The sample holder was the same as was used for the fluorescence measurements. Prior to data analysis, the visual/NIR reflectance spectra were converted to $\log(1/R)$ units, where R denotes the reflectance.

2.4. Fourier-transform infrared spectroscopy

The FT-IR spectra were measured in the range 950–4000 cm^{-1} with an Arid-zone MB100 FT-IR interferometer (ABB Ltd., Québec, Canada). An attenuated total reflectance (ATR) device with multiple reflexions was used for collecting the data (ZnSe 45°; Spectra-Tech Inc.; CT; USA). Each sample was measured by averaging 32 spectra and presenting these in relation to a single-beam spectrum of the clean ATR crystal. The resolution was 4 cm^{-1}, and the collected data were converted into absorbance units.

2.5. Low-field nuclear magnetic resonance

The LF-NMR relaxation measurements were performed on a 23.2 MHz Maran bench top pulsed ^{1}H NMR analyzer (Resonance Instruments Inc., Witney, UK) equipped with an 18 mm variable temperature probe. The samples were introduced into the NMR probe by filling approximately 5.8 g of cheese into LF-NMR glass tubes. The transverse relaxation time constants (T_2) of the samples were measured using the Carr-Purcell-Meiboom-Gill (CPMG) pulse experiment (Carr & Purcell, 1954; Meiboom & Gill, 1958). The CPMG experiments were carried out using a relaxation delay of 10 s and 16 consecutive scans for noise reduction, with a filter width of 0.1 MHz. The top points of 4 K consecutive echoes were acquired using a tau of 150 μs to properly describe the relaxation decay. Only even-numbered echoes were used in the data analysis.

2.6. Sensory analysis

A full descriptive analysis was carried out by a trained panel (10 participants). This paper only considers the results for the parameter "creaminess". Other details about results from the sensory analysis are reported elsewhere (Johansen, Laugesen, Janhøj, Ipsen, & Frøst, 2008; Janhøj et al., 2006, 2008). During training sessions, the panellists were instructed to use their own idiosyncratic concept of "creaminess". This approach was chosen to better indicate individual differences in the perception of "creaminess". Even though there were individual differences in rating of creaminess, it was found that the panellists agreed sufficiently on the term to make a good discrimination of the 18 products. Samples were scored on a computer screen using a 15-cm unstructured scale labelled with "a little" and "a lot" 1 cm from the end points. The samples were measured in triplicate and average values were used in the data analysis. The least squared difference (LSD-value) was