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Evaluating Mid-infrared Spectroscopy as a New Technique for Predicting Sensory Texture Attributes of Processed Cheese

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ABSTRACT

The objective of this study was to investigate the potential application of mid-infrared spectroscopy for determination of selected sensory attributes in a range of experimentally manufactured processed cheese samples. This study also evaluates mid-infrared spectroscopy against other recently proposed techniques for predicting sensory texture attributes. Processed cheeses (n = 32) of varying compositions were manufactured on a pilot scale. After 2 and 4 wk of storage at 4°C, mid-infrared spectra (640 to 4,000 cm^{-1}) were recorded and samples were scored on a scale of 0 to 100 for 9 attributes using descriptive sensory analysis. Models were developed by partial least squares regression using raw and pretreated spectra. The mouth-coating and mass-forming models were improved by using a reduced spectral range (930 to 1,767 cm^{-1}). The remaining attributes were most successfully modeled using a combined range (930 to 1,767 cm^{-1} and 2,839 to 4,000 cm^{-1}). The root mean square errors of cross-validation for the models were 7.4 (firmness; range 65.3), 4.6 (rubbery; range 41.7), 7.1 (creamy; range 60.9), 5.1 (chewy; range 43.3), 5.2 (mouth-coating; range 37.4), 5.3 (fragmentable; range 51.0), 7.4 (melting; range 69.3), and 3.1 (mass-forming; range 23.6). These models had a good practical utility. Model accuracy ranged from approximate quantitative predictions to excellent predictions (range error ratio = 9.6). In general, the models compared favorably with previously reported instrumental texture models and near-infrared models, although the creamy, chewy, and melting models were slightly weaker than the previously reported near-infrared models. We concluded that mid-infrared spectroscopy could be successfully used for the nondestructive and objective assessment of processed cheese sensory quality.

Key words: descriptive sensory analysis, processed cheese, mid-infrared spectroscopy, chemometrics

INTRODUCTION

Over 18 million tonnes of cheese were produced worldwide in 2004, and processed cheese is an important segment of this market (Wohlfarth and Richarts, 2005). The United States, the largest producer of processed cheese (where 20% of all cheese consumed is processed cheese), produced 1,092,000 tonnes in 2003 (Wohlfarth and Richarts, 2005). In the same year, the 25 countries of the European Union produced 655,000 tonnes of processed cheese (Wohlfarth and Richarts, 2005).

Consumer preference for a food product is principally determined by its sensory characteristics. Accurate monitoring and control of sensory properties will facilitate the production of high-quality products. A number of factors determine the final quality and sensory properties of processed cheese (Carić and Kaláb, 1993). These include the processing conditions used during manufacture, the composition of the ingredients, and the proportions of those ingredients added to the blend.

Sensory profiling allows various quality attributes to be identified and their intensity determined (Brown et al., 2003). Sensory attributes are traditionally assessed by descriptive sensory evaluation using trained panelists. However, this is a time-consuming and expensive process that may lack objectivity (Blazquez et al., 2006). Although instrumental techniques such as texture profile analysis (**TPA**) and the 3-point bend test are available for determining the texture attributes of food products, these laboratory-based techniques are time-consuming and require the use of skilled personnel in their execution (Blazquez et al., 2006). Therefore, considerable interest exists in the development of instrumental techniques to enable more objective, faster, and less expensive assessments of cheese quality to be made, including sensory aspects (Downey et al., 2005). Such a technique would assist producers to maximize yields, increase

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throughput and efficiency, reduce labor costs, and optimize product quality, consistency, and customer satisfaction. Critical points in the manufacturing process could be monitored to ensure that the final product would meet required specifications.

Recently, Kealy (2006) examined cream cheese using TPA, one of the main instrumental techniques for texture measurement, and compared the results with those of a trained taste panel. Although a reasonably strong correlation was found between the taste panel results and TPA-derived hardness and adhesiveness parameters, the correlation for cohesiveness was not straightforward. Everard (2005) also investigated the prediction of sensory attributes of processed cheese from instrumental texture attributes derived from TPA, a compression test, and a 3-point bend test. He could predict the texture attributes of firmness, rubbery, creamy, chewy, fragmentable, and mass-forming with a good level of accuracy (Everard, 2005).

Spectroscopic analysis in combination with predictive mathematical models, developed using multivariate data analysis techniques such as partial least squares (**PLS**) regression, have potential use in controlling and monitoring the quality of raw materials through to the final product in food processing. In particular, infrared spectroscopy has been applied as an objective and nondestructive technique to provide a rapid and real-time analysis of both composition and quality (Downey, 1998; Lefier et al., 2000; Ozen and Mauer, 2002; Blazquez et al., 2004). Blazquez et al. (2006) modeled the sensory attributes of processed cheese using near-infrared reflectance spectroscopy and PLS regression. They found that it was possible to model a number of attributes including firmness, melting, rubbery, and creamy. Two other studies have investigated the prediction of sensory attributes in natural cheese. Downey et al. (2005) and Sørensen and Jepsen (1998) successfully demonstrated that near-infrared spectroscopy in conjunction with PLS regression can be used to predict several sensory attributes of Cheddar and Danbo cheeses, respectively. Mid-infrared spectroscopy has been most widely used for determination of the fat and protein contents of cheese (Chen and Irudayaraj, 1998). Irudayaraj et al. (1999) also investigated the use of mid-infrared spectroscopy to follow texture development in Cheddar cheese during ripening. They demonstrated that springiness could be successfully correlated with a number of bands in the mid-infrared spectra. Research has shown that mid-infrared spectroscopy is a useful technique for characterizing the changes in proteins during cheese ripening (Mazerolles et al., 2001). Pillonel et al. (2003) also found that mid-infrared spectroscopy may be successfully applied to the discrimination of Emmental cheese based on geographic origin.

Table 1. Quantity of ingredients (g/kg) used in the production of experimental processed cheese samples

Sample number(s)	Cheddar	Butter	Water	Emulsifying salt
1, 10	838.7	0.0	161.3	9.7
2	838.7	0.0	151.6	19.4
3, 11	838.7	0.0	141.9	29.0
4, 12	838.7	51.6	112.9	9.7
5, 13	838.7	51.6	100.0	19.4
6, 14	838.7	51.6	90.3	29.0
7, 15	838.7	100.0	61.3	9.7
8	838.7	100.0	51.6	19.4
9, 16	838.7	100.0	41.9	29.0
17, 25	848.4	51.6	103.2	9.7
18, 26	838.7	51.6	100.0	19.4
19, 27	829.0	51.6	100.0	29.0
20, 28	751.6	45.2	203.2	9.7
21, 29	745.2	45.2	203.2	19.4
22, 30	738.7	45.2	200.0	25.8
23, 31	651.6	38.7	303.2	16.1
24, 32	645.2	38.7	303.2	22.6

No data are currently available on the application of mid-infrared spectroscopy to determine the sensory attributes in processed cheese, or regarding evaluation of mid-infrared spectroscopy in comparison with other technologies in such an application. Therefore, the objectives of this study were to investigate the use of mid-infrared spectroscopy in predicting sensory texture attributes using a range of experimentally manufactured processed cheese samples and to compare the models developed with those recently modeled using near-infrared spectra and instrumental texture attributes. These newly presented data allow for the critical evaluation of mid-infrared spectroscopy as a rapid, nondestructive technique for predicting the sensory texture attributes of processed cheese.

MATERIALS AND METHODS

Processed Cheese Samples

Thirty-two processed cheese batches were manufactured in a pilot plant at Moorepark Food Research Centre, Cork, Ireland. The ingredients and formulations are listed in Table 1. The formulations, which were selected to provide samples with compositional ranges that extended beyond those used commercially by processed cheese manufacturers, provided samples with a wide range of sensory characteristics. The ingredients were mixed for 1 min in a jacketed cooker (Stephan UMM/SK5 Universal cooker; Stephan u Söhne GmbH & Co., Hameln, Germany). The blend was cooked at 80°C for 2 min by indirect steam heating. During cooking, the blend was stirred constantly using a knife at 300 rpm and a baffle mixer at 80 rpm. The cooked blend was stored in food-grade plastic containers (225 g capacity),

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