Empirical and Dynamic Rheological Data Correlation to Characterize Melt Characteristics of Imitation Cheese

J.S. Mounsey and E.D. O’Riordan

ABSTRACT

Imitation cheese was manufactured with various levels of pregelatinized maize starch. Melt characteristics were assessed by an empirical melt test, based on the Olson and Price method. Using dynamic rheology, the storage modulus (G’), the loss modulus (G”) and the loss angle (tan δ) were measured as a function of temperature (22–100°C). Meltability decreased with increasing levels of starch. Maximum tan δ values and the temperature at which they occurred decreased with increasing starch levels. A high correlation (r² = +0.96) was found between the maximum tan δ values and meltability as assessed by the empirical method. Tan δ may be a useful indicator of imitation cheese meltability.

Key words: meltability, imitation cheese, empirical test, dynamic rheology, tan δ

INTRODUCTION

IMITATION CHEESE IS GENERALLY MANUFACTURED FROM CASEIN or its derivatives, vegetable fats or oils, salts, acids and flavorings, and is used as a cost effective substitute for natural cheese. Meltability is an important functional characteristic of imitation cheese due to its widespread use as an ingredient in pizza. The empirical methods most commonly used to assess meltability of cheese are also applied to imitation cheese. These include the Schreiber (Kosikowski, 1982), Olson and Price (1958) and Arnott (Arnott et al., 1957) methods. The Schreiber and Arnott methods involve measuring changes in the dimensions of a cheese cylinder treated at high temperature in an oven. Olson and Price (1958) used the distance cheese flowed in a glass tube placed in an oven for 6 min at 110°C as an index of meltability. The simplicity and speed of such empirical methods is attractive, especially for quality assurance in an industrial environment. However, for research purposes their lack of objectivity is a distinct disadvantage. Attempts have been made to develop objective methods to examine the properties of cheese. Capillary rheometry (Smith et al., 1980) and differential scanning calorimetry (Tunick et al., 1989) have been proposed with little success to assess cheese meltability.

Dynamic rheology is a fundamental method that has been used for several applications in cheese research. It has been applied to distinguish between imitation and natural Mozzarella cheeses. Meltability is a distinct disadvantage. Attempts have been made to develop objective methods to examine the properties of cheese. Capillary rheometry (Smith et al., 1980) and differential scanning calorimetry (Tunick et al., 1989) have been proposed with little success to assess cheese meltability.

Imitation cheese is primarily consumed in its molten state and, consequently, its melted properties are critical to its usefulness as a food ingredient. The meltability of imitation cheese has been assessed using subjective tests (Lindsay et al., 1980; Kratochvil, 1987) and empirical methods (Hokes et al., 1982; Song and Park, 1986; Savello et al., 1989; Cavalier-Salou and Cheftel, 1991; Abou El-Nour et al., 1996); however, there has been limited characterization of the meltability of imitation cheese using fundamental methodology. The objective of this study was to assess the usefulness of dynamic measurements as indicators of imitation cheese meltability.

MATERIALS & METHODS

Manufacture of imitation cheese

An imitation cheese product was manufactured with 41.6% water, 26.3% rennet casein (Kerry Ingredients, Listowel, Ireland), 27.9% vegetable fat (Tribly Trading Ltd., Liverpool, England), 1.82% emulsifying salts (1.16% trisodium citrate, 0.66% citric acid (Jungbunzlauer, Pernhofen, Austria), 0.52% disodium phosphate (Ellis and Everard, Ireland) and 0.11% sorbic acid (Hoehst Ireland Ltd., Dublin, Ireland) using a twin-screw cooker (model CC-010, Blentech Corporation, Rohnert Park, CA). All ingredients (except citric acid) were blended in the cooker at 35°C and heated to 78°C using direct steam. Citric acid was added, and after 5 min mixing the product was packaged, cooled to 4°C and vacuum-packed (model C 10 H, Wehomatic, Bochum, Germany) 24 h later. Using a similar process, six imitation cheese products containing 2, 3, 4, 5, 7, or 9% starch were prepared by replacing equivalent quantities of casein in the standard formulation with pregelatinized maize starch (National Starch and Chemical, Manchester, England). Three 4-kg batches of each cheese were manufactured.

Compositional analysis

Samples of imitation cheese were analyzed for moisture (IDF, 1958), fat (National Standards Authority of Ireland, 1955), protein (IDF, 1993) content and pH (model 9450 pH meter, Unicam Ltd., Cambridge, England). All analyses were performed in triplicate.

Empirical melt test

A modification of the Olson and Price (1958) method was used to assess meltability. Cylinders (25 mm dia, 40 mm ht) were cut from blocks of imitation cheese, wrapped in aluminum foil and tempered to 10°C. The foil was then removed and the cylinders were individually placed into one end of a Pyrex glass tube (250 mm l, 30 mm dia). The end containing the cheese was closed with a solid rubber stopper, and the opposite end was plugged with a stopper, pierced with a hole to allow gas to escape. The tubes were placed horizontally in a conventional oven at 180°C for 15 min. The tubes were removed from the oven, and the distance flowed from a reference line was measured in mm and used as an indication of meltability. Four samples from each block of imitation cheese were assessed.

Dynamic rheological test

Dynamic oscillatory measurements were performed on a controlled stress rheometer (model SR 2000, Rheometrics Inc., Piscataway, NJ) fitted with a 25-mm parallel plate with a 2.4-mm gap.
Disc-shaped samples of cheese (24 mm dia, 2.4 mm thick) were prepared using a slicer and borer. The samples were placed on the lower plate and compressed 0.2 mm to prevent slippage. All measurements were made in a controlled environment chamber at a frequency of 1 Hz. Strain sweep experiments (0.1–10% strain) were undertaken to establish the linear viscoelastic region, and temperature sweeps were performed within this region. The temperature of the samples was increased from 22°C to 100°C at 6°C/min using a Peltier heating element. Parameters measured included the storage modulus ($G'_0$), the loss modulus ($G''_0$) and the loss angle ($\tan \delta (G'/G'')$). Six samples from each block of imitation cheese were assessed.

### Table 1—Compositional analysis of imitation cheese

<table>
<thead>
<tr>
<th>Added starch, (%)</th>
<th>Protein (%)</th>
<th>Fat (%)</th>
<th>Moisture (%)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20.5±0.3</td>
<td>25.6±0.3</td>
<td>49.1±0.1</td>
<td>5.88±0.03</td>
</tr>
<tr>
<td>2</td>
<td>17.8±0.1</td>
<td>26.4±0.2</td>
<td>48.8±0.3</td>
<td>5.80±0.04</td>
</tr>
<tr>
<td>3</td>
<td>16.9±0.1</td>
<td>26.1±0.2</td>
<td>48.9±0.02</td>
<td>5.75±0.07</td>
</tr>
<tr>
<td>4</td>
<td>16.0±0.1</td>
<td>26.0±0.0</td>
<td>48.5±0.2</td>
<td>5.74±0.02</td>
</tr>
<tr>
<td>5</td>
<td>15.2±0.3</td>
<td>26.0±0.2</td>
<td>48.9±0.2</td>
<td>5.78±0.01</td>
</tr>
<tr>
<td>7</td>
<td>12.9±0.3</td>
<td>25.8±0.4</td>
<td>48.7±0.3</td>
<td>5.75±0.02</td>
</tr>
<tr>
<td>9</td>
<td>11.0±0.1</td>
<td>25.9±0.4</td>
<td>48.7±0.04</td>
<td>5.78±0.04</td>
</tr>
</tbody>
</table>

**Statistical analysis**

PROC GLM of SAS (SAS Institute, Cary, NC) was used to determine differences between treatments means and correlation coefficients. Treatment means were considered significantly different at $P \leq 0.05$ unless stated differently.

**RESULTS & DISCUSSION**

The compositional analyses of the imitation cheeses manufactured were compared (Table 1). All imitation cheese products had similar fat (26.0±0.25), moisture (48.8±0.21) and pH (5.78±0.05) values. Protein content decreased as starch content increased.

A modification of the method of Olson and Price (1958) was used to assess meltability. Modifications involved altering the sample dimensions and increasing both the test temperature (110°C to 180°C) and the test time (6 to 15 min). The heat treatment was typical of the cooking procedure for convenience foods containing imitation cheese, e.g., pizza. This modified method generated reproducible data with typical coefficients of variations ranging from 4.2 to 8%. These compared favorably with variations reported by Park et al. (1984) using the Schreiber test (4 to 7.2%) and the Arnott test (14.7 to 19.5%) to assess meltability of processed and imitation cheeses. Results indicated that meltability of the imitation cheese decreased ($P<0.01$) with increasing starch (Fig. 1). The product containing no starch had a melt value of 151.3±6.4 mm. Addition of 2% starch reduced the melt by almost 33% to 1027.3 mm and inclusion of 9% starch resulted in a product with negligible meltability (9.25±1.28 mm). Results indicated that meltability of imitation cheese could be manipulated by the addition of pregelatinized maize starch. Imitation cheese with poor melting characteristics is often desirable when used in products that are deep-fat-fried. Poor meltability of process or rennet casein-based process cheese has been associated with a high degree of fat emulsification as evidenced by the size distribution of fat globules determined by electron microscopy (Rayan et al., 1980; Savello et al., 1989).

A strain sweep (0.1 to 10%) was used to determine the limits of linear viscoelastic behavior of imitation cheese (Fig. 2). Results indicated that stress was proportional to strain when strain values were < 1%. Results were in agreement with findings for natural cheeses. Nolan et al. (1989) and Ak and Gunasekaran (1996) reported stress/strain linearity for several cheese varieties at strains <2%. As shown (Fig 2.), the storage modulus ($G'_0$) of imitation cheese decreased, the loss modulus ($G''_0$) remained unchanged and, accordingly, the loss angle ($\tan \delta$) increased on increasing the strain from 1 to 10%. Yun et al. (1994) had reported a decrease in $G'_0$ with increasing strain for natural Mozzarella cheese; however, the $G'_0$ and $G''_0$ were reported to cross over at a strain of 10%, which we did not observe. $\tan \delta$ values measured at 22°C were 0.4, 0.35, 0.35, 0.34, 0.32, 0.31 and 0.28 for samples containing 0, 2, 3, 4, 5, 7 and 9% starch, respectively. These values were typical of those reported for natural cheese (Diefes et al., 1993; Hsieh et al., 1993; Tunick et al., 1993; Yun et al., 1994).

$\tan \delta$ values for the imitation cheese were also measured as a function of temperature (Fig. 3). As the temperature increased from 22–90°C the $\tan \delta$ values for the 0% starch product increased, indicating that the elastic component decreased to a greater extent than the viscous component. $\tan \delta$ values of imitation cheeses containing 2, 3, 4, 5, 7 or 9% starch increased on increasing the measuring temperature from 22 to 74.5, 74, 80, 72, 69 or 63.5°C, respectively, but no further increase in $\tan \delta$ was observed above these temperatures. The maximum $\tan \delta$ values observed in the range 22–100°C decreased with increasing starch ($P<0.01$) reflecting the tendency of starch to retard meltability. Results suggested that imitation cheeses containing pregelatinized maize starch maintained their elastic properties on heating to a greater extent than those products containing no starch.

The relationship between the maximum $\tan \delta$ values observed in the range 22–100°C and the meltability of imitation cheese as deter-
CONCLUSION

DYNAMIC RHEOLOGY MAY PROVE TO BE A USEFUL FUNDAMENTAL method to assess the meltability of imitation cheese products. This would facilitate comparison of results from different studies and improve our understanding of the melting properties of cheese.

REFERENCES


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