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Melting Characteristics of Cheese

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치즈의 融解性質에 관한 연구

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Abstract

The traditional methods of testing the meltability of cheese, the Schreiber and the Arnott test, were reviewed and compared. The limitations of such methods were examined. Different sensitivities were observed for these two tests. In the Schreiber test, sharp Cheddar showed highest meltability, followed by process American, mild Cheddar, and Mozzarella. In the Arnott test, however, the rank changed to Mozzarella, mild Cheddar, sharp Cheddar, and process American. Process cheese products showed very dispersed values. Meltability increased quickly until about 4 *min* and held constant after 5 *min* in the Schreiber test. In the Arnott test, it started to increase after 5 *min* and held constant after 15 *min*. The constant meltabilities shown after certain times were caused by scorching or case hardening which prevented further flow. The DSC-thermogram showed endothermal peaks at about 14 and 30 °C. These peaks can be accounted for by the fusion of butter fat during heating.

Introduction

A good cheese has to possess certain rheological properties according to its intended use, e.g. cream cheese which is often used as a spread should be soft and smooth, hard cheeses such as Cheddar or Swiss should have sliceability. In some cases, the properties after melting are very important. For example, the stringing quality of a stretched curd cheese such as Mozzarella has promoted its use in hot dishes such as pizza and lasagna. American process cheese is used to top hamburgers or hot sandwiches because it melts quickly and evenly. The melting characteristics of direct acidified cheese products attracted the attention of several researchers since inadequate melting appeared to be the most serious problem associated with such products.[1] These melting characteristics include such parameters as meltability (degree of melting), free fat separation, stringiness, and appearance of melted cheese.[2]

Relatively little investigation has been conducted on cheese melting characteristics. Arnott et al.[3] first suggested a melting quality test for Cheddar and processed cheese. This test consisted of heating a cylindrical sample (17×17*mm*) at 100 °C for 15 *min*, the measurements of cylinder height before and after heat treatment were used as a melting index. After this, researchers, e.g. Olson et al.[4], Breene et al.[1], Chang[5], Kovacs et al.[6], and Kosikowski[7], conducted different meltability tests or melting quality studies on cheese. These methods consisted of measuring the final dimensions of standard-sized samples after they had been heated in an oven or over a boiling water bath for a set time. These methods are empirical and not well-defined and were used only as an arbitrary means of describing the melting quality of cheese.

Some researchers attempted to use viscometry to determine melting properties. Lee et al.[8] used a Brookfield viscometer to determiine the melting properties of cheese by the changes in viscometer readings with rise in temperature, and Smith et al.[9] investigated the use of a capillary rheometer to study cheese melt flowability.

In general, the various meltability tests were used to correlate meltability with certain other properties such chemical properties[3], extent of proteolysis[10-13], hardness[14], method of manufacture[15-19], degree of emulsification[2,12] and stabilizing capability[6].

In spite of these studies, work is still needed to charaterize the melting properties of cheese. The absence of sensitive tests for melting characteristics may well be attributed to the lack of understanding of the nature and mechanisms of the phenomenon of melting.

The objectives of this research were 1) to review and compare the traditional meltability tests of cheese, 2) to evaluate the test conditions (heating time and cheese type), 3) to investigate the applicability of a thermal behavior test based on Differential Scanning Calorimetry.

Materials and Methods

Material

Commercial cheeses for which meltability is impor-

Table 1. Traditional meltability tests

Cheese type	Sample Size		Measurement	Heating medium temp. (°C)	Heating time	Heater	Ref.
	Dia. (*mm*)	Height (*mm*)					
Process Cheddar	17	17	percent decrease in height	100	15 *min*	oven	3
Cheddar	17	17	time required for melting (*sec.*)	80	—	water bath	14
Cheese spread	30	20	distance of flow from reference line (*mm*)	110	8 *min*	forced draft oven	4
Pizza	15	5	percent decrease in height & increase in dia.	98	5 *min*	water bath	1
Process	19.1	6.4	percent increase in dia.	232	3 *min*	oven	5
Cheese spread	38.1	4.8	dia. increase by flow line number	204	5 *min*	oven	6
Process	40.6	4.8	dia. increase by flow line number	232	5 *min*	oven	7
Process	37.5	7.5	percent increase in diameter	250 & 100	5 *min* & 15 *min*	oven	12
Caseinate curd	—	—	melt area per unit weight (cm^2/g)	—	15 *sec*	micro-wave oven	20

tant were selected for this study. They were Cheddar (mild and sharp), Mozzarella (low moisture part skim), process American, and process cheese product. Six to twelve ounces (about 170 to 340*g*) of cheese were used for sampling. All cheeses were stored at 4 °C in plastic bags to minimize moisture losses. For testing, standard-sized samples were made by the following procedure:

Cylinders of cheese were obtained with cork borers or a sharp-edged copper cylinder according to the required diameters. Disks or cylindrical samples were cut from the plug with a device consisting of tube through which the plug of cheese in pushed against an adjustable stop, and a wire which is pulled down through the slot. In case of sliced cheese, samples were obtained by stacking thin cheese slices to give desired thickness and inserting a sharp-edged copper cylinder or cork borers.

The Arnott Test

All cheeses were kept at 4°C for 24 hours prior to sampling. Sampling was conducted using a size 13 cork borer and a cutting device as previously mentioned. The cylinders of cheese (17*mm* in diameter, 17*mm* in height) were placed on glass petri dishes (15x100*mm*). The initial heights of cheese samples were measured with a tripod depth micrometer (Fig. 2). The micrometer barrel was lowered to the surface of the sample and a reading recorded when the barrel made contact with the center of the cheese cylinder. This procedure was also carried out on the melted samples. The petri dishes were covered and returned for 30 *min* to a refrigerator maintained at 4 °C. After this period, the sample was placed in an oven at 100 °C for 15 *min*. Then the sample was removed and cooled on a flat surface at room temperature for 30 *min*. The final sample height was measured. The center of the cheese cylinder was selected for the final measurement, regardless of the surface slope or depression. Meltability was expressed in terms of percent decrease in cylinder height after heating.

The Schreiber Test

The Schreiber test was used as described by Kosikowski.[7] A cheese disk 3/16 inches thick and 1.6 inches in diameter was positioned in the center of a thin-walled glass petri dish (15x100*mm*). The sample was returned with cover to a refrigerator maintained at 4 °C for 30 *min*. It was then placed with cover in a convection oven at 232 °C (450 °F) for 5 *min*. After removing the petri dish from the oven, the sample was cooled on a flat surface for about 30 *min*. Subsequently, the degree of spreading was measured by using a concentric numbered target-type graph based on concentric circles starting at 1.6 inches in diameter (labeled 0) and increasing by 0.1 inch (labeled 1,2,3, etc.).

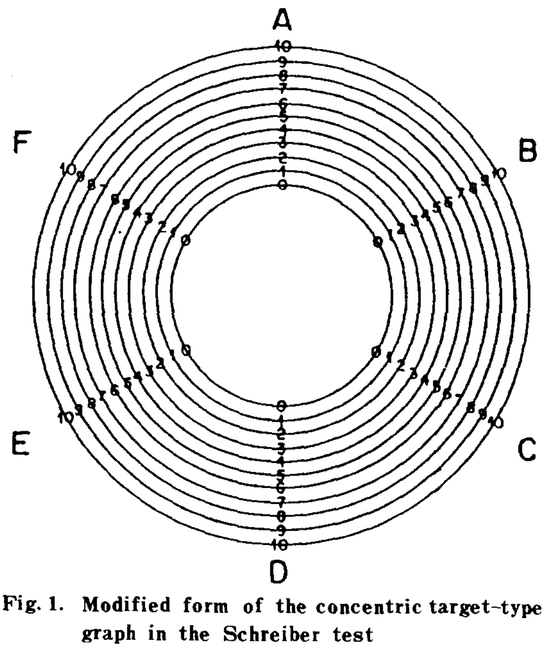

Fig. 1. Modified form of the concentric target-type graph in the Schreiber test

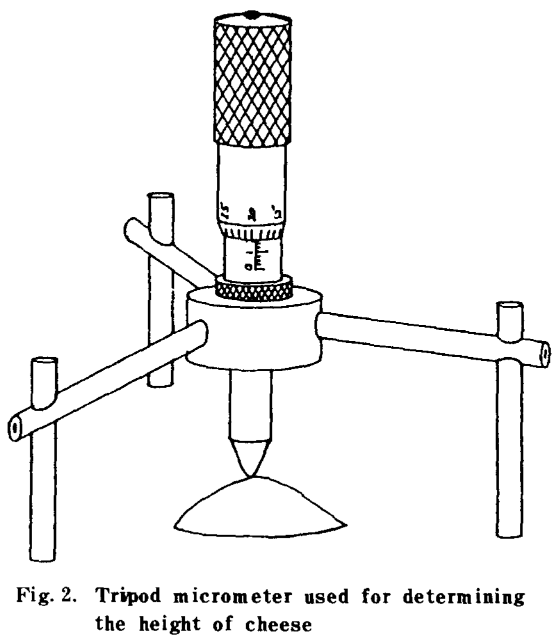

Fig. 2. Tripod micrometer used for determining the height of cheese

As the cheese does not melt uniformly, i.e. its shape is not always a true circle, the reading method described by Kosikowski was modified as follows:

1. Six directions were marked in a concentric numbered target-type graph (Fig. 1).

2. Meltability values were indicated by the average of the readings which are the numbers of the circle containing the outer edge of the melted sample in each direction.

3. Standard deviations of the six numbers were calculated for an index of uniformity of flow.

All the data for the Schreiber test in this study were obtained by this modified reading method.

Thermal Analysis of Cheese

A perkin-Elmer Model DSC-2 differential scanning calorimeter (Perkin-Elmer Corp., Norwalk, Conn.) was used for thermal analysis. The DSC (Differential Scanning Calorimeter) measures the differential energy required to keep both sample and reference at the same temperature throughout the analysis. When a heat transition such as melting, boiling, dehydration, or crystallization occurs in the sample material, the energy absorbed by the sample is replenished by increased energy input to the sample to maintain temperature balance and this balancing energy or change in power required is recorded as a peak because this energy input is equivalent in magnitude to the energy absorbed in transition.

In this study, a temperature range, 4 to 80 °C, was used. 20 to 25 *mg* cheese samples were placed in aluminum pans and scanned in a DSC-2 with empty sample holders as references. The DSC scans were made at a heating rate of 5 °*C/min*. Instrument sensitivities of 2 to 20 *mcal/sec* were used. The chart speed was 20 *mm/min*.

Results and Discussion

To compare the traditional meltability tests, the Schreiber test and the Arnott test were selected for this study. For the purpose of comparison, the Arnott scale versus Schreiber scale was plotted in Fig. 3. Fig. 3 gives support to the hypothesis that "Meltability" includes more than one physical property and that the two tests respond differently to these properties. In other words, data from one test can not be used to predict scores from the other test.

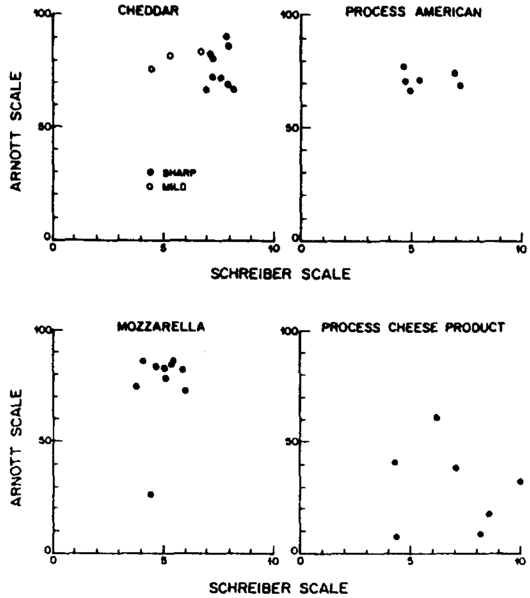

Fig. 3. **Plot of Arnott scale versus Schreiber scale of meltability**

Generally, in the Schreiber test, sharp Cheddar had the highest meltability, followed by process American, mild Cheddar, and Mozzarella. In case of sharp Cheddar cheese, data were not significantly different. Mild Cheddar showed lower values than sharp Cheddar. In the Arnott test, however, the rank order changed to Mozzarella, mild Cheddar, sharp Cheddar, and process

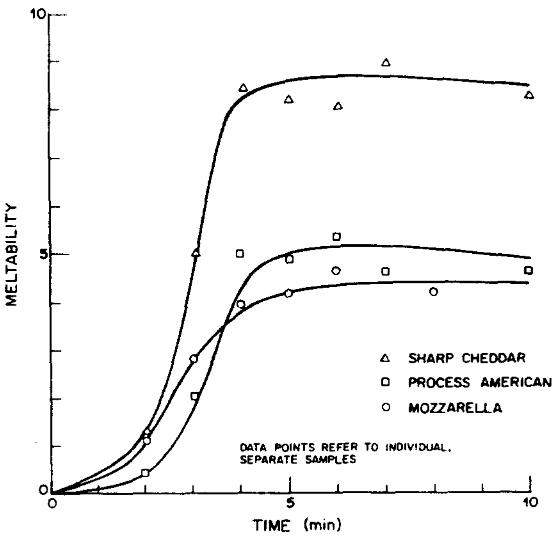

Fig. 4. **Meltability change with time in conventional oven (the Schreiber test)**

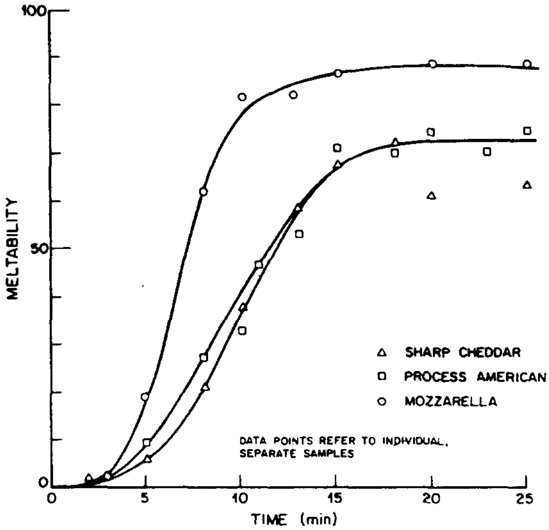

Fig. 5. Meltability change with time in conventi-ontional oven (the Arnott test)

American. Process cheese products had very dispersed values and usually low values, especially in the Arnott test scale.

Fig. 4 and 5 show meltability changes with time for the Schreiber and Arnott tests. Three kinds of cheeses, i.e. sharp Cheddar, process American and Mozzarella, were used for this study. In Fig. 4, it can be seen that meltability increases after 2 *min*, changes quickly until about 4 *min*, and holds fairly constant after 5 *min*. Cheddar cheese showed highest values and process American showed a little higher values than Mozzarella. Fig. 5 shows the meltability change in the Arnott test. Meltability starts to increase after 5 *min* and holds constant after 15 *min*. Mozzarella cheese showed highest values at each time; process American and sharp Cheddar showed similar curves. Constant meltabilities after certain times were caused by scorching or case hardening which prevents further increase in meltability. This indicates that good repeatabilities can be obtained at certain times in both tests.

DSC thermograms of three different types of cheese were recorded (Fig. 6). Endothermal peaks at about 14 °C and 30 °C were found. These peaks did not indicate significant endo-or exo-thermal effects other than those expected due to the fusion of butter fat[21]. Endothermal reactions due to changes in the structure of the protein present were not detected in the thermograms in these temperature ranges.

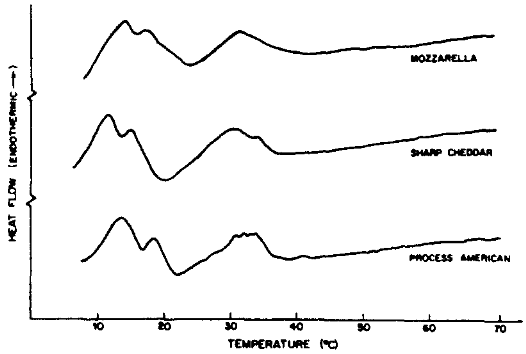

Fig. 6. Thermogram of three kinds of cheese in the temperature range 4° to 80°C (single samples)

In conclusion, the results of this study confirm that the Arnott and Schreiber tests respond differently to the changes in melting properties noted among different cheeses. Test results from one can not be used as a sole predictor of the other. This suggests that recommendations for testing methods must depend on the desired melting properties required by the product application. For example, if the flow characteristics of a particular application are important, e.g. the use of shredded cheese as a pizza topping, the Schreiber test would most likely to be appropriate. If softening characteristics are important but the cheese is the one that exhibits little flow, e.g. grilled cheese sandwich or cheese burger applications, then the Arnott test might be better.

요 약

치즈의 融解程度(meltability)를 측정하는 전통적인 방법중 대표적인 2가지 방법, 즉 Schreiber방법과 Arnott방법을 비교 검토하였다. 같은 시료에 대해 두가지 방법이 서로 다른 融解程度를 나타내었다.

Schreiber 방법에서는 sharp Cheddar가 가장 높은 값을 나타내었으며, 그 다음으로 process American, mild Cheddar, Mozzarella의 順이었고, Arhott 방법에서는 그 순서가 바뀌어서 Mozzarella, mild Cheddar, sharp Cheddar, process American의 順이었다. Process cheese product는 分散된 값들을 보여 일정한 경향을 나타내지 못하였다. 두가지 방법 모두 一定時間 加熱後에는 一定한 融解程度를 보여주었으며 이것은 scorching이나 case hardening에 의해 더 이상의 흐름을 防止하였기 때문으로 생각된다. DSC-Thermogram은 14도와 30도 근처에서 endothermal peak를 보여주었다. 이들은 加熱時 乳脂肪의 融解에 의한 것으로 설명된다.

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