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MELTING PROPERTIES OF BUTTER FAT AND THE CONSISTENCY OF BUTTER
Effect of modification of cream ripening and fatty acid composition

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Abstract

The cold unspreadable consistency of butter after taking it out of the refrigerator is a rightful objection on behalf of consumers. The possibilities to improve the cold spreadability of butter are: the enrichment with low melting point triglycerides and the application of a good cream-ripening method. In our investigations milk fat fractions of different low melting points and plant oils of low melting points obtained by cold pressing and extraction have been used to change the original fatty acid composition of milk fat. The cream-ripening, the traditional method and the heat-step ripening method, which seemed to be the most effective to our earlier research, have been applied. The consistency of butter was examined by penetration measurements and its thermal characteristics by differential scanning calorimetric (DSC) method. The cold unspreadable consistency of butter can only be improved by the combination of the heat-step cream ripening and enrichment with low melting point triglycerides to get stable consistency at room temperature. The milk fat fraction of melting point below 5°C made the spreadability better but the spreadable consistency of margarine still cannot be attained. Plant oils with melting point below 0°C improved the cold spreadability of butter to a significantly higher degree than the former did. In the case of the same melting point the plant oil obtained by a cold method (pressing) was more effective. There is a close relationship between the consistency of butter and its product characteristics. From DSC curves the cold spreadability and room temperature stability of butter can be directly concluded.

Keywords: butter, cold spreadability, DSC, plant oils

Introduction

In recent decades the decrease of butter and increase of margarine consumption have been experienced all over the world. This is mainly due to the nutritional propaganda,

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the change of price ratios, the functional characteristics and the inferior cold spreadability of butter compared to margarine.

Nutritional propaganda is based on the so-called lipid theory launched by the American Ancel KEYS, according to which the cholesterol and the higher saturated fatty acid content of animal fats are blamed for arteriosclerosis, and ultimately for cerebrovascular catastrophe and heart attack [1, 2]. In spite of the fact that the KEYS theory is scientifically disproved and the real nutritional value is given back to butter compared to the ‘artificial fat’ margarine [3, 4], advertising still suggests the opposite, and is totally accepted by public opinion in Hungary [5].

A real disadvantage of butter is its cold unspreadable consistency. On fresh white bread, which constitutes the greater part of consumption in Hungary, margarines can be easily spread immediately after removing them from the refrigerator while butters cannot. For this reason, the decrease of consumption of butter creams (butter products of an oil-in-water emulsion system), which are even more spreadable than margarines, was less than that of butters [5].

It is common to apply different cream ripening methods to influence the consistency of butter. The spreadability of winter butter can be improved by the cold-warm-cold ripening method. At the same time, the consistency of summer butters can be made firmer by warm-cold-cold ripening methods by determining the temperatures of ripening on the basis of the crystallization and melting curves of milk fat [6, 7].

The butter consistency can also be changed by fractions obtained from milk fat crystallized at different temperatures. More spreadable butters can be made from a low melting point fraction [8] while butters produced from a high melting point fraction are more stable at a high (34°C) temperature [9].

The different scanning calorimetric investigations of the melting characteristics of butter fat make it probable that the butter structure obtained by the combination of cream ripening and enrichment with a low melting point fraction can result in a cold good spreadable butter consistency [10]. The melting DSC-curves of the low and high melting point fractions obtained by fractionation of milk fat differ from that of milk fat both in respect of the peak temperatures and the size of area under the curves, i.e. enthalpy values [8, 11]. But, we did not find any data on the melting and crystallization properties of butters made by the combination of enrichment with a low melting point milk fat fraction and special milk fat ripening methods making firm and softening the consistency of butter cold, respectively.

Materials and methods

Cream obtained in winter period was used in the experiments. The fatty acid composition of its fat corresponded to that detailed in our previous work [10].

To modify the fatty acid composition, three milk fat fractions of different melting points were used. The fraction of 20°C melting point (LMP-20) was made in a laboratory by crystallizing anhydrous milk fat at 20°C, then separating the liquid and the crystallized milk fat to low and high melting point fractions by filtration at the same temperature. Milk fat fractions of 15°C (LMP-15) and 10°C (LMP-10) melting points were obtained from the Belgian firm Corman.

In all series of experiments the raw material was the same cream which was divided in two parts following pasteurization. The experimental arrangement is shown in Table 1.

Table 1 Main technological parameters of butter samples not enriched and enriched with milk fat fraction and made of cream ripened traditionally and by the heat step method

Technological operations	Parameters of technological operations			
	Traditional ripening		Heat step ripening	
	Not enriched	Enriched	Not enriched	Enriched
Pasteurization	at 92°C			
Cooling	to 6°C			
Heating	to 11°C		to 20°C	
Ripening	at 11°C		at 20°C	
Cooling	–		to 11°C	
Enrichment	–	LMP fraction		LMP fraction
Butter making	at 11°C	at 11°C	at 11°C	at 11°C

In order to examine the consistency properties, the butter samples were stored for 48 h at 5°C, then for 24 h at the temperature of the measurements. To determine consistency firmness, the penetration value (*P*) of the samples was measured at four different temperatures in the temperature range of 5–25°C using the cone shown in Fig. 1. at a load of 102.5 g. The penetration value (*P*) is the depth of penetration of the cone into butter sample expressed in 0.1 mm over 5 s. The thousandfold value of the reciprocal of the penetration value (F=1000/P) was used for the characterization of the firmness of butter samples. The firmness, calculated in such a way, as a function of temperature, provides almost a straight line as shown in Fig. 2.

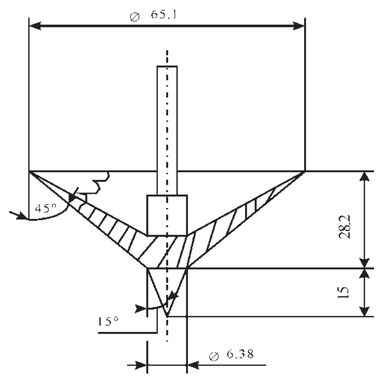

Fig. 1 Sizes of the measuring cone of penetrometer used for determination of butter firmness

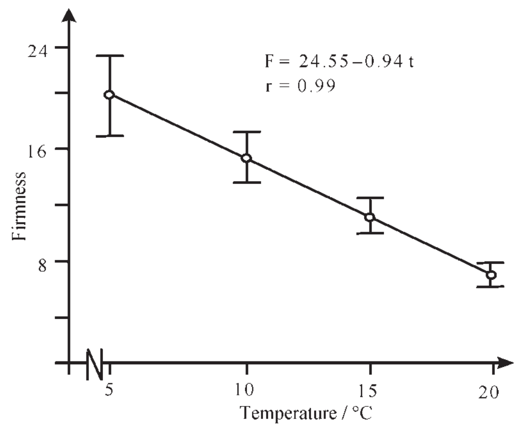

Fig. 2 Average values of firmness of butter samples (*F*) and their standard deviations as a function of temperature (*t*) and the correlation coefficient (*r*) of the matching line

Cream was physically ripened: the traditional ripening the so-called summer ripening method, i.e. warm-cold-cold process and the heat-step ripening the so-called winter ripening method, i.e. cold-warm-cold process was used with the parameters given in Table 1. Enrichment with the low melting point fraction was done immediately before the butter making. A SETARAM Micro DSC-II type ultra-sensitive scanning calorimeter was used in calorimetric measurements. Mass of the sample changed between 700–900 mg and a traditional batch measuring cell pair of 1 ml volume was used in the experiments. The reference material was ethyl alcohol. The measurements were carried out in the temperature range of 0–50°C with the heating and cooling rate of 0.3°C min^{-1}. In all cases the experiments were started after the adjustment of thermal balance when the fluctuation of heat flow was below 0.5 μW. For the characterization of the effect of temperature change the temperatures belonging to transitions and the transition enthalpies were applied.

To characterize the consistency properties of different butter samples, a straight line was plotted to the firmness values of the samples measured by a penetrometer at different temperatures as a function of temperature.

Results

In Fig. 3 the melting (b) and the crystallization (a) DSC-curves of the low melting point milk fat fraction (LMP-10) used in the experiments are demonstrated. Figure 3 shows that up to the temperature of 10°C the fraction will be totally melted and the crystallization begins at 5°C. The average maximum temperature values of the melting and crystallization peaks are 4.2 and 2.4°C.

In Fig. 4A the melting DSC-curves of butters made of cream ripened traditionally (a, c) and by the heat step method (b, d) and not enriched (a, b) and enriched (c, d) with 25% LMP-10 milk fat fraction are shown. The effect of the ripening method and that of

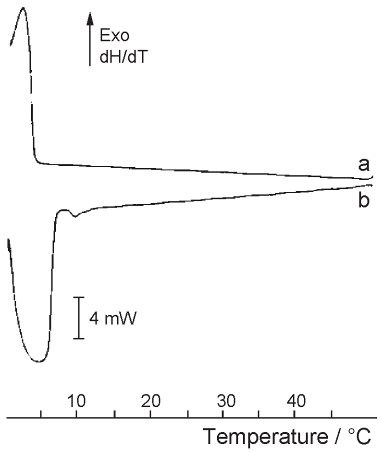

Fig. 3 DSC curves of melting (b) and the crystallization (a) of (LMP-10) milk fat fraction

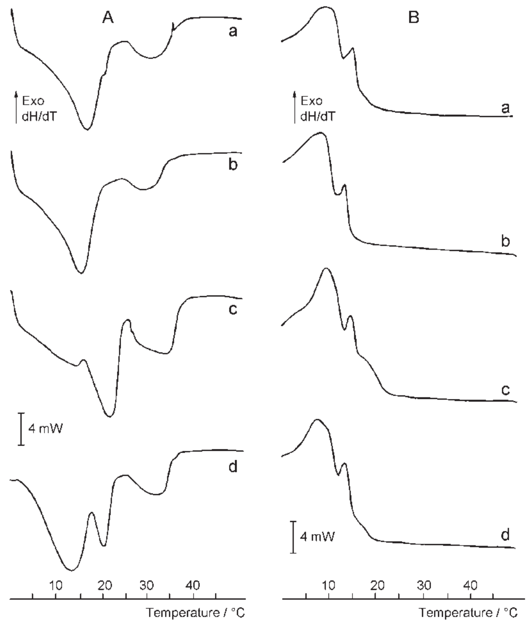

Fig. 4 DSC curves of melting (A) and the crystallization (B) of butter made of cream ripened traditionally (a, c) and by the heat step method (b, d) not enriched (a, b) and enriched (c, d) with 25% LMP-10 milk fat fraction

the enrichment with the low melting point fraction on the melting characteristics of butter fat is well demonstrated in Fig. 4A. The heat step ripening results in a differentiation in milk fat fraction of a melting point below 25 °C, the originally one peak is breaking down into two peaks which indicates the decomposition of this fraction to another two ones.

Due to the effect of the enrichment with the LMP-10 milk fat fraction, the temperature maximum of milk fat fraction melting at temperature below 20°C of butter made of cream ripened traditionally moves towards the lower temperature. However, in the case of heat step ripening the temperature values of the double peak remain unchanged, but the increased enthalpy-value of the peak belonging to the lower temperature indicates melting of a significantly higher extent. The part of the melting curves above the temperature of 25 °C is not influenced by the ripening method and they change similarly under the effect of the addition of LMP-10 milk fat fraction, the temperature range is shifting towards the lower temperature values.

The above mentioned facts are supported by Table 2, where the average values and standard deviations of the characteristic temperatures red off the melting curves are summarized.

Table 2 The characteristic melting temperatures of butter samples and their standard deviations

Ripening method	Content of LMP-10 fraction/%	Melting temperature/°C	
		T_{M1}	T_{M2}
Traditional	0.0	16.08±0.08	
Traditional	25.0	14.60±0.10	
Heat step	0.0	13.08±0.15	20.62±0.42
Heat step	25.0	13.32±0.26	20.12±0.34

Based on the data, it is obvious that in the case of traditional ripening there is a significant difference between the temperature values of the melting peaks of butter not enriched and enriched with LMP-10 fraction. Such a significant difference cannot be detected at the heat step ripening method.

The enthalpy values belonging to the double melting peak below 25°C of butter made of cream ripened by the heat step method are shown in Table 3. The starting point of the baseline fitting to the decomposition was the intercept of the two straight line fitted on the DSC curves in the 0–5°C temperature range. It can be seen from Table 3, that due to the enrichment with LMP-10 fraction the enthalpy of the part of the lower temperature increased significantly at the expense of the part of the higher temperature.

Table 3 Enthalpy-values of the double melting curve of butter samples made of cream ripened by the heat step method

Content of LMP-10 fraction/%	Melting temperature/°C	Melting enthalpy/J g^{-1}
0.0	13.08	10.0
	20.62	18.0
25.0	13.32	16.0
	20.10	11.0

In Fig. 4B the crystallization DSC-curves of butters made of cream ripened traditionally (a, c) and by the heat step method (b, d) and not enriched (a,b) and enriched (c,d) with 25% LMP-10 milk fat fraction are shown. It is well demonstrated in Fig. 4B that during preliminary heating the difference due to ripening has disappeared in the structure, the character of the curves is the same. The enrichment with LMP-10 fraction decreased the temperature of both crystallization peaks. The average temperature values together with their standard deviations are shown in Table 4. It is obvious on the basis of the data of Table 4, that there is no significant difference between the temperature values of the crystallization peaks as a function of ripening, however, the difference caused by the addition of a low melting point fraction is significant.

Table 4 The characteristic crystallization temperatures of butter samples and their standard deviations

Ripening method	Content of LMP-10 fraction/%	Crystallization temperature/°C	
		T_{K1}	T_{K2}
Traditional	0.0	15.18±0.08	9.58±0.13
Traditional	25.0	13.46±0.23	8.12±0.13
Heat step	0.0	15.16±0.15	9.68±0.19
Heat step	25.0	13.48±0.18	8.08±0.15

The effects of the enrichment with different amounts of a milk fat fraction of 20°C melting point (LMP-20) on the consistency firmness of butters made of traditionally and heat-step ripened cream are shown in Fig. 5 as a function of temperature. It can be seen from Fig. 5, that in the case of both ripening methods the addition of milk fat fraction LMP-20 to butter, at a low (below 10°C) temperature decreases the firmness of butter, i.e. improves its spreadability, proportionally to the increase of its amount. However, at room temperature (about 20°C) the values of consistency firmness are almost the same. It is also well demonstrated that all enriched versions of traditionally ripened butters are firmer at a low temperature than the samples of heat-step ripened butters, and also that the slope of the straight lines is greater.

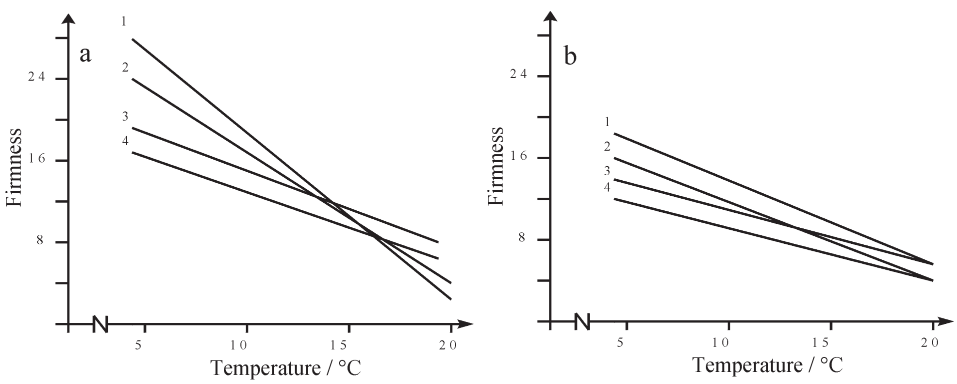

Fig. 5 Consistency firmness of butters made of traditionally (a) and heat step (b) ripened cream containing 0% (1), 15% (2), 25% (3) and 30% (4) of LMP-20 milk fat fraction referred to milk fat as a function of the temperature

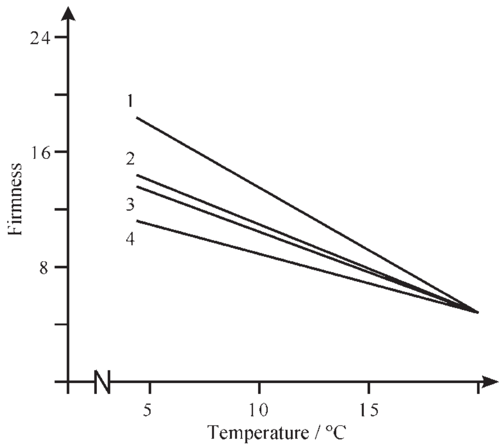

Fig. 6 Consistency firmness of butters made of cream ripened by heat step method and not enriched (1) and enriched with 25% LMP-20 (2), LMP-05 (3) and LMP-10 (4) milk fat fraction referred to milk fat as a function of the temperature

The consistency firmness of butter samples made of heat-step ripened cream not enriched and enriched with milk fat fractions of 20, 15 and 10°C melting points in the amount of 25% of milk fat is shown in Fig. 6 as a function of temperature. It is well demonstrated in Fig. 6, that the consistency firmness of butter decreases in proportion to the decrease of the melting point of the fraction at a low (below 10°C) temperature. However, the values of consistency firmness are very similar at room temperature (about 20°C).

The consistency firmness of butters made of heat-step ripened cream enriched with a milk fat fraction of 10°C melting point (LMP-10) to a different degree, measured at 5°C, is shown in Fig. 7 as a function of the ratio of LMP-10 fraction. It is ob-

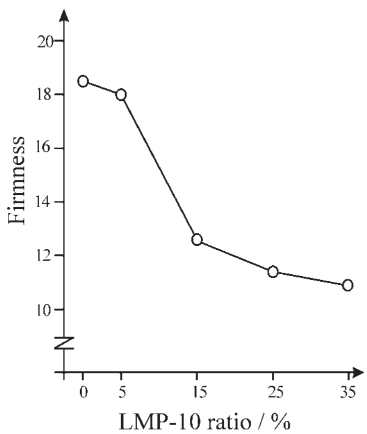

Fig. 7 Consistency firmness of butters made of cream ripened by heat step method and not enriched and enriched with LMP-10 fraction at 5°C as a function of the ratio of LMP-10

vious in Fig. 7 that the consistency firmness decreases proportionally to the increase of LMP-10 milk fat fraction. The degree of the decrease in consistency firmness is considerable up to the proportion of 25% but is smaller above this value.

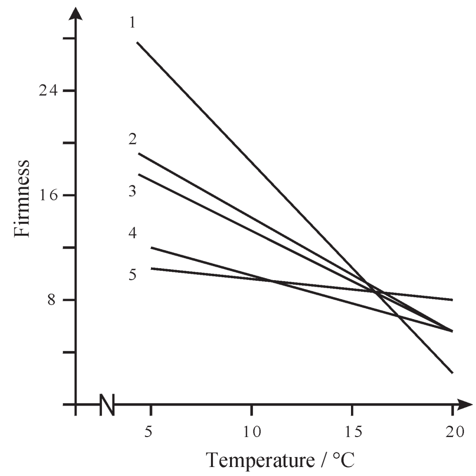

Fig. 8 Consistency firmness of butters made of cream traditionally (1), heat step ripened and not enriched (2) and of cream containing 25% LMP-10 milk fat fraction traditionally (3) and heat step (4) ripened and that of a spreadable margarine (5) as a function of the temperature

The consistency firmness of butters made of traditionally and heat-step ripened cream and their versions enriched with 25% LMP-10 milk fat fraction and that of a margarine considered well spreadable by consumers is presented in Fig. 8 as a function of temperature. It can be seen in Fig. 8 that there is a difference between butter made of traditionally ripened cream and margarine. Butter is much firmer than margarine at a temperature of 5°C but it softens more quickly parallel to the increase of temperature, and at 17°C margarine attains a firmer consistency. The rise of the curve of firmness-temperature of non-enriched butter made of heat-step ripened cream is somewhat more favourable. This butter is more spreadable cold and softens less under temperature increase than does traditional butter. Almost the same result can be attained if butter made of traditionally ripened cream is enriched with LMP-10 milk fat fraction in 25%. However, the consistency of butter made of heat-step ripened cream and containing 25% LMP-10 milk fat fraction is practically the same as that of well spreadable margarine.

Conclusions

The structural differences between butters made of traditionally and heat step ripened cream known from literature have been proved by the thermoanalysis of butters carried out by the ultra-sensitive DSC-method.

Based on electronmicroscopic investigations it can be stated that due to the heat step cream ripening milk fat fractionation goes on inside the fat globules as follows. While the high melting point fraction becomes concentrated in a crust on the surface of fat globules, the low melting point fraction accumulates partly in a crystallized, partly in a liquid form in the core of fat globules [12]. During the butter making the so-called particle structure is formed providing a better cold spreadability. The reason is that the continuous phase consisting of low melting point triglycerides provides 'oiling' to the particles having mainly high melting point triglycerides [13, 14].

Milk fat fractionation occurring in fat globules due to ripening and existing also in butter has been detected directly by the ultra-sensitive DSC-method. Here, in the range of 0–25 °C, owing to the heat step ripening two fractions have been measured instead of one fraction of the traditional ripening.

The differences of the structure are also supported by our statement that while the addition of LMP-10 fraction decreases the melting temperature of fat being in homogenous continuous phase in the case of traditional ripening, it does not make any difference in the case of heat step ripening. The shifting of enthalpy values refer to the concentration of LMP-10 fraction in the low melting point part of the fractionated fat due to ripening.

Compared to butter made of traditionally ripened cream, both the heat-step ripening and the enrichment with a low melting point milk fat fraction results in a softer consistency of butter at a low temperature (below 10°C) and consequently a better spreadability. The rise of the curve of consistency firmness-temperature decreases, so butter softens less when temperature is increased. Cold spreadability will improve if the melting point of LMP-fraction is decreased and its ratio is increased.

Our findings harmonize with the already existing knowledge on butter structure [6, 7, 10, 13–17]. The traditional cream ripening method resulting in mainly homogeneous structure of butter can provide cold well spreadability and warm heat stability to butter made of winter cream neither if it is enriched with a low melting point milk fat fraction. Contrary to this, the heat-step cream ripening combined with the enrichment with a low melting point fraction can provide such a spreadable consistency as margarine has.

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