HARDNESS OF BUTTER. I. INFLUENCE OF SEASON AND MANUFACTURING METHOD[1]

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SUMMARY

Hardness was measured on weekly samples of conventionally churned and continuously made butter,[2] taken over a period of 1 yr. Penetrometer and sectility methods were used at 17 and 12° C., respectively. The continuously made butters were consistently harder than the conventionally churned butters. Similar seasonal variations were found for both butters and were greater than differences between the two butter types at 17° C. Hardness maxima occurred simultaneously with softening-point minima, as determined previously. Hardness of conventional butter was less influenced by the experimental temperature difference than was that of the continuous type butter. The hardness of the continuous type butter decreased as gas was added and, therefore, gas content may be a partial cause of the hardness differences between the two butter types. A major portion of the setting of the continuous butter occurred during the first 3 hr. after manufacture and was attributed to crystallization, which was still in progress. The hardening taking place after this first period was attributed to thixotropic changes.

Extensive hardness increase, assumed to be caused by thixotropic changes, occurred in conventional butter and extended over approximately 1 wk. Setting was prevented in both butters during storage at low temperature (−20° C.), but resumed a normal course on subsequent removal of the butter to higher storage temperatures. A permanent hardness decrease was imparted to both butter types by storage at 20-22.5° C.

It has been shown that butterfat in this region is subject to considerable seasonal variation in chemical composition *(13)*, and it is a well-known fact that such changes will profoundly influence the hardness of butter. In a preliminary investigation, continuously made butter was found to be harder than conventional butter *(14)*. The difference was attributed to the remarkable dissimilarity in crystalline structure, but differences in gas content of these two types of butter also may be partly responsible.

Conventional butter increases considerably in hardness subsequent to removal from the churn. This phenomenon is generally called setting, and has been attributed to thixotropic changes. When a study is made of the influence of manufacturing method on hardness, the setting should be considered an important factor. Storage temperature of the finished butter is also important as a factor influencing the course of hardness changes and should, therefore, receive attention.

The present report is a study of the influence of season and manufacturing method on the hardness of butter. The manufacturing methods chosen were the conventional churning and the fundamentally different continuous method.

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[2] Made by a process known as Gold'n Flow, which is copyrighted by the Cherry-Burrell Corp., Chicago, Illinois.

METHODS

Hardness was measured either by the penetrometer method at 17° C. or by the sectility method at 12° C. The penetrometer method was a modification of the procedure described by Kruisheer and den Herder *(7)*. The disk plunger of 4 cm.^{2} surface area was mounted in an apparatus similar to the Swift consistometer described by Clardy *et al.* *(1)* and moved at 5 cm/min. Each butter sample was prepared for hardness measurement immediately after manufacture, by being pressed into a square frame of 5-cm. side and 2.9-cm. height, fabricated from a 20-gauge stainless steel sheet. For certain experiments, it was necessary to use continuous type butter from the experimental continuous buttermaking machine developed in this Department *(15)*, and for this purpose the butter was extruded directly into 2.9-cm. lengths of 2-in. O.D. stainless steel tubing.

At lower temperatures, the resistance to penetration exceeded the range that could be recorded by the gauge of the apparatus, and a sectility method was substituted. This was achieved by replacement of the disk by a taut stainless steel wire (diameter 0.015 in.) held in a frame. The gauge reading was taken when the wire had travelled 2.5 cm. through a block of butter which had first been pushed from its frame.

The butter samples, unless otherwise stated, were kept in the frames at 5-10° C. for 1 wk., then tempered in a water bath for 24 hr. prior to testing. Water bath temperatures of 17° C. in the penetrometer method and 12° C. in the sectility method were maintained thermostatically within ±0.05° C., and measurements immediately followed removal of the samples from the water bath, in a room having a temperature in the range 5-10° C.

Each hardness value reported, unless otherwise specified, is the average of two determinations. Penetrometer hardness is expressed as kg/4 cm.^{2}, whereas sectility is expressed as kg/5 cm., since 5 cm. was the length of the wire in contact with the butter.

RESULTS

Accuracy of methods. To test the accuracy of the methods, ten replicate samples of continuously made and ten of conventional butter were measured by both penetrometer and sectility methods. From the results (Table 1), it appears that the accuracy of the methods is very satisfactory.

TABLE 1

The accuracy of hardness measurements

	Conventional butter		Continuous butter	
	Penetrometer method	Sectility method	Penetrometer method	Sectility method
Range [a]	2.00 – 2.12	0.24 – 0.26	3.94 – 4.14	1.02 – 1.08
Mean	2.05	0.25	4.05	1.05
Av. deviation from mean	± 1.5%	± 4.0%	± 1.4%	± 2.1%

[a] Ten replicate samples of each type of butter.

Round frames gave very slightly higher penetrometer hardness than square frames when the butter was hard, but not when the butter was soft (Table 2).

TABLE 2

Influence of shape of frames on butter hardness values

Description of sample	Penetrometer hardness $(Kg/4\ cm.^2)$	
	Round frames	Square frames
Hard butter [a]	2.40	2.20
Soft butter [a]	0.84	0.84

[a] Average of four samples each.

Seasonal variation. For a period of 1 yr., butter samples were collected weekly from two local creameries. One manufactured butter by the continuous method and the other by the conventional method. The monthly averages of hardness of each butter type at two temperatures are given (Figure 1). It is to be noted that the butter types follow the same general hardness trend throughout the year (for the penetrometer hardness data, r =.81, significant at the 1% level). This indicates that the difference in physical structure is responsible for

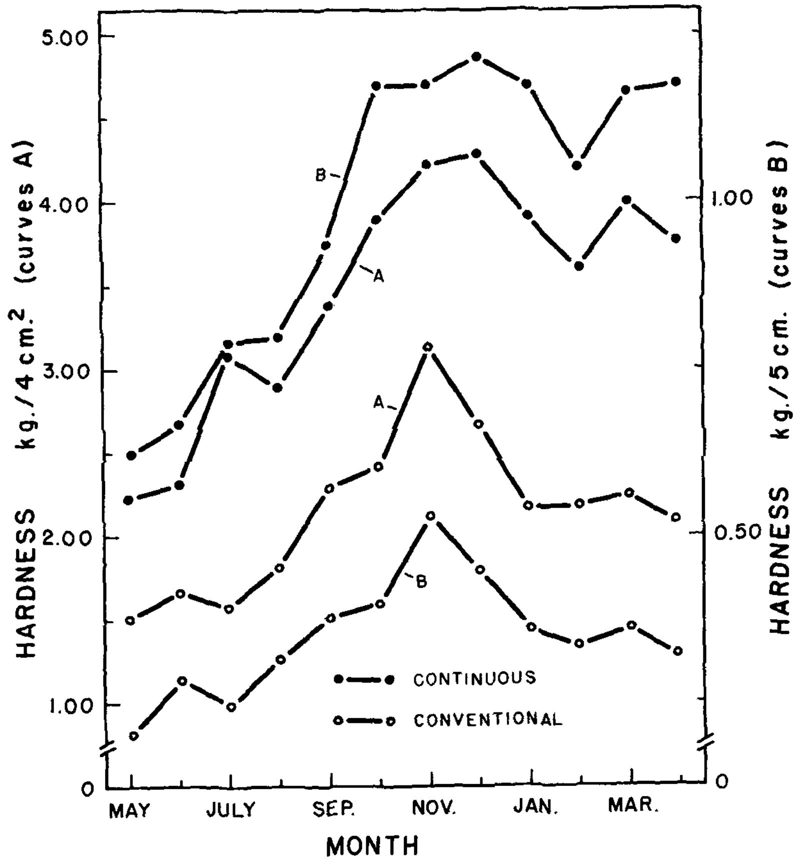

FIG. 1. Comparative hardness of continuous and conventional butter. Curves A: penetrometer method. Curves B: sectility method.

the increased hardness found in the continuous butter, as previous work *(13)* established that the chemical composition of the butterfat of these two Edmonton creameries did not differ significantly. The maximum hardness of both butters occurred in November-December, when the softening point of the butterfat of this region is at maximum value *(13)*; and, conversely, minimum hardness of the butter and minimum softening point of the butterfat coincided seasonally.

The penetrometer and sectility values show a high correlation (for conventional butter, r =.98, and for continuous butter, r =.95, both significant at the 1% level).

Comparative hardness. It is evident (Figure 1) that on any sampling date the continuously made butter was harder than the conventional butter. The difference was found to be significant at the 1% level.

A remarkable further difference in the hardness properties is revealed in Figure 1. When a point of equal hardness is chosen on the penetrometer curves of each type of butter, it is found that the corresponding sectility values are widely different. The sectility hardness value for conventional butter is then seen to be considerably lower. Thus, the hardness of conventional butter appears to be less influenced by these temperature differences than is the hardness of the continuous butter, since sectility was measured at a lower temperature than was penetrometer hardness.

Influence of gas content. In a preliminary study of the influence of the gas content of butter, samples of continuous type butter with varying nitrogen content were prepared with the experimental continuous machine. The presence of the gas materially lowered hardness values (Table 3).

TABLE 3

Influence of gas content on hardness of experimental continuous type butter

Sample	Gas content	Penetrometer hardness
(No.)	*(%)*	*($Kg/4\ cm.^2$)*
1	0	2.60
	2.0	2.40
	3.6	2.02
2	0	2.48
	1.0	2.28
	16.0	1.68
3	0	2.76
	1.2	2.76
	4.0	1.88
	17.5	1.88

The incidental observation was made, as reported elsewhere *(2)*, that stickiness became apparent in the continuous butter as gas content was increased. The differences in gas content of continuous and conventional butter may explain the differing stickiness of the two butter types.

Setting. A sample of each butter type, taken immediately after completion of manufacture, was maintained in a constant temperature water bath for eight days at the initial temperature, i.e., 5° C. for continuous butter and 12.5° C.

for conventional butter. In this way, the influence of temperature changes on hardness was eliminated. Hardness was measured at these temperatures hourly for 6 hr. and daily thereafter.

Sectility hardness of butter made by the continuous method increased rapidly for the first 6 hr. and less rapidly thereafter (Figure 2). To measure temperature changes that accompanied this setting, samples of butter emerging from the texturator were immediately placed in tempered Dewar flasks. The temperature increased from 8.7 to 11.8° C. in 2 hr. (Table 4) and remained fairly constant thereafter.

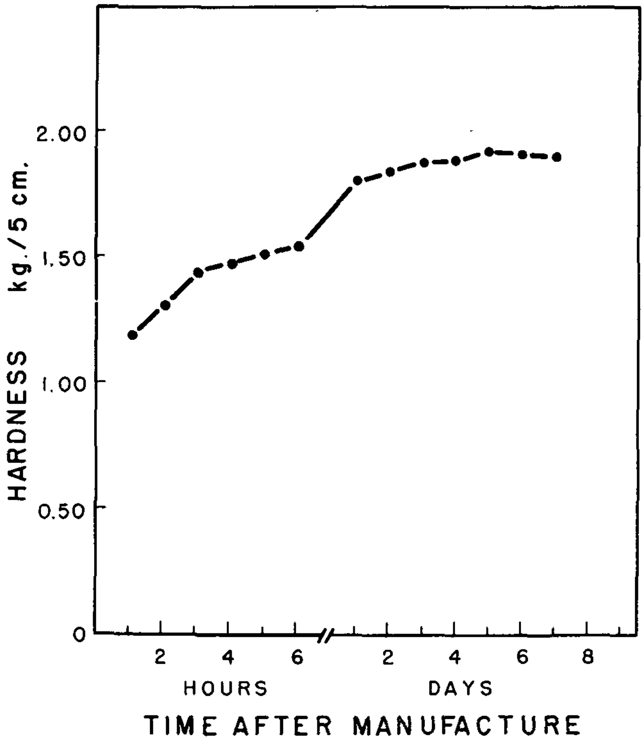

FIG. 2. Sectility hardness values during setting of continuous butter.

TABLE 4

Temperatures of continuous and conventional butters stored in Dewar flasks

Type	Temperature ° C.						
	Initial	¼ hr.	½ hr.	1 hr.	2 hr.	3 hr.	4 hr.
Continuous	8.7	10.5	11.1	11.5	11.8	11.9	11.9
Conventional	14.9	15.0	15.0	15.0	15.0	—	—

When conventional butter was held at the temperature that prevailed when the working was completed, 12.5° C., hardness increased for eight days (Figure 3), but the temperature of the butter stored in Dewar flasks remained con-

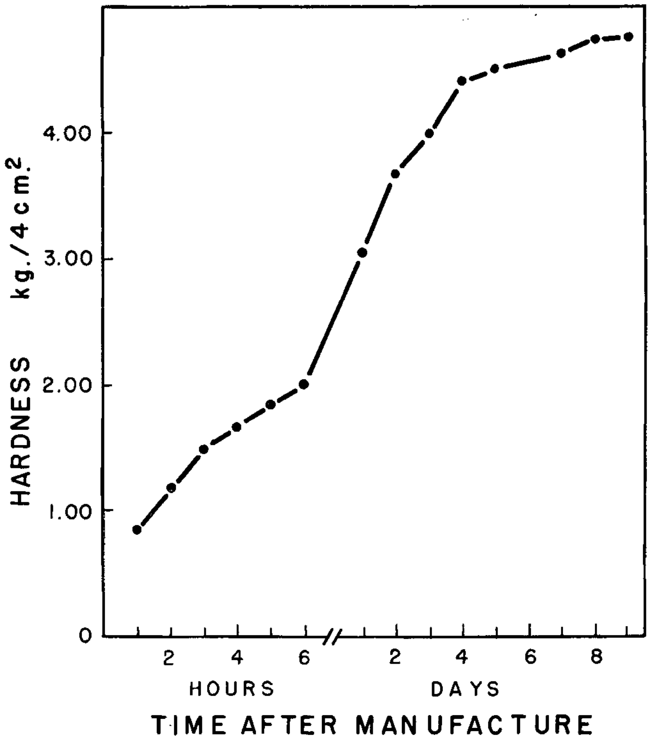

FIG. 3. Penetrometer hardness values during setting of conventional butter.

stant (Table 4). The increasing hardness of conventional butter apparently is a consequence of crystal orientation only, as the crystallization of the butterfat is essentially complete when the working of the butter is finished. In the continuously made butter, however, the hardness increase is largely caused by crystallization, and thixotropic changes are less pronounced.

When replicate samples of each type of butter were stored at 5° C., the penetrometer hardness increase was greater in the conventional butter (Table 5).

TABLE 5

Hardness changes during setting at 5° C.

Days after manufacture	Penetrometer hardness—(*kg/4 cm.*^{2})	
	Continuous	Conventional
1	3.90	1.76
3	3.96	2.00
7	4.12	2.34

Storage of the butters at −20° C. completely prevented setting, and no measurable hardening occurred. On subsequent removal to 5° C. storage, hardness increased to the same level as in the butters stored at 5° C. immediately following manufacture.

In a further study of the effect of storage temperature, replicate samples of each butter type were accorded the storage treatments as set forth in Table 6, and penetrometer hardness was measured weekly. To minimize changes related to setting, all samples were stored for the first week at 5° C. Freezing temperature again interrupted hardness increase in each type of butter, but setting was resumed after the butters were removed to 5° C. storage. One week of storage of either butter at 22.5° C. had a remarkable and permanent softening effect. In investigating this phenomenon further, an equivalent softening effect required 2 wk. at 20° C., in place of 1 wk. at 22.5° C., whereas 17.5° C. was ineffective.

TABLE 6

Influence of storage temperature on butter hardness

		Penetrometer hardness—*(Kg/4 cm.^{2})*, after				
Butter type	Treatment[a]	1 wk.	2 wk.	3 wk.	4 wk.	5 wk.
	A	2.76	2.84	2.84	2.84	2.88
Continuous	B	2.76	2.74	2.74	2.85	2.89
	C	2.76	1.20	1.25	1.18	1.20
	A	1.88	2.10	2.12	2.16	2.16
Conventional	B	1.88	1.86	1.88	2.04	2.14
	C	1.88	1.16	1.18	1.14	1.16

[a] Treatment: A—5 wk. at 5° C; B—1 wk. at 5° C., 2 wk. at −20° C., and 2 wk. at 5° C.; C—1 wk. at 5° C., 2 wk. at 22.5° C., and 2 wk. at 5° C.

DISCUSSION

A large number of methods and instruments has been used for measuring rheological properties of butter. Unfortunately, there is uniformity neither in terminology nor in interpretation of results. Some methods have been adapted to the determination of exact physical properties, e.g., viscosity *(3, 8, 11)*; others have been linked to subjective assessments *(7, 10)*. Hardness of butter is usually measured within the range of 12-17° C., and in choosing measurement temperatures the important consideration is that the range of hardness values encountered falls within the range of the particular instrument used. In this investigation, all samples could be measured by the penetrometer method at 17° C. and by the sectility method at 12° C.

The meaning of the term spreadability is rather vague, and some investigators are of the opinion that spreadability and hardness are not directly related *(10, 12)*; on the other hand, the most widely used methods are of the penetrometer and sectility types.

Hardness has been defined as "a measure of the resistance to permanent deformation or damage" *(9)*. If this definition is accepted, penetrometer, sectility, spreadability, and other methods are all fundamentally hardness measurements, although the results are not always directly comparable.

The high correlation between penetrometer and sectility methods indicates that the same hardness property was measured; whereas, in recently reported work *(5)* on the spreadability and hardness of butter, a highly significant correlation was obtained between spreadability and sectility measurements.

The hardness of butter made by the continuous method, by comparison of corresponding weekly samples, was always significantly higher than that of conventional butter, and similar seasonal changes occurred in the two types of butter. There exists considerable difference in the physical structure of the two butters (crystal structure, gas content, water dispersion), which accounts for the dissimilar hardness. It is to be noted that the penetrometer hardness difference between the two butters does not reach the magnitude of inherent seasonal variations. Dolby *(4)* estimated that up to 80% of differences in hardness of conventional butter were caused by seasonal variations in the composition of the butterfat. Considerable interest has been shown in attempts to influence rheological properties of conventional butter by variation of temperatures before and during churning. The continuous process undoubtedly represents an extreme treatment, as the fat is subjected to rapid cooling and agitation in the chilling compartment, but even this results in penetrometer hardness changes that are low in comparison to seasonal differences.

On the basis of the limited data herein presented, it would be premature to assign to gas content a major role in butter hardness, or to proportion continuous and conventional butter hardness differences between gas content and crystal state.

The extreme hardness increase in conventional butter during the first week after manufacture is attributed to orientation of the crystal particles into a rigid structure, as no indication of crystallization was found during this period. Crystallization is still proceeding in continuous butter as it emerges from the texturator and part of the hardness increase is, therefore, caused by increase in number and/or size of crystal particles.

There was no hardness increase caused by orientation of crystal particles during storage of the butter at low temperature (−20° C.). Contrary to results reported recently *(6)*, the interruption of setting by freezing was found to be not permanent. It is probable that in the aforementioned study the butter was not allowed enough time after freezing to obtain maximum hardness, as suggested by the data reported *(6)*. The influence of setting on hardness deserves further study. At high temperature (20-22.5° C.), the crystalline structure undergoes a breaking-down process and hardness is permanently lowered. It is of interest to note that, at the latter storage temperature, both types of buttter (made at the same time of year) had approximately the same hardness at the end of the experiment.

The role of the state of crystallization in hardness differences will be the subject of further communication.

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