TEXTURAL ASSESSMENT OF TABLESPREADS WITH EMPHASIS ON CANOLA BASED PRODUCTS

BY

BEVERLEY KAYE VANE

A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

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Winnipeg, Manitoba, 1981

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ABSTRACT

Products evaluated were butter and brand name margarines made from canola, corn, soy and sunflower oils. Corresponding brick and tub market forms of each margarine, plus an additional canola brick were included. During the latter part of the study, storage stability of canola products was tested by comparing stored and fresh products. Measurements of firmness and work to soften, obtained using trained sensory panels and the General Foods texturometer, and sensory assessments of spreadability, rate of mouthmelt and graininess were made at 4°C and 21°C. Textural qualities were related to fatty acid composition and to melting properties defined by solid fat indices (SFI) and differential scanning calorimetry (DSC).

Canola products had levels of less than 5% cis-cis,9-12 octadecadienoic acid (cis-cis C18:2) and the highest levels of trans fatty acids, greater than 40% in brick products. Corn and sunflower products of both market forms had levels of cis-cis C18:2 exceeding 25%.

Textural analysis showed that brick products, all of which contained greater than 40% trans plus saturated fatty acids, were significantly firmer, more difficult to work soften, less spreadable and were more slowly melting than the tub products. The larger proportion of the high melting fraction in brick products provided higher SFI values at 10°C and was reflected as a lower percentage of melt at temperatures below 4°C, as seen on DSC thermograms, compared to the tub products. Ca-

nola products, the brick market form more specifically, and the sunflower products were significantly more likely to have graininess observed in them than products from the other oil sources. Tests of the effect of storage on graininess and subsequently on the textural properties were inconclusive. Products with SFI values of less than 17 were considered to be ideally spreadable by the panel; DSC melt information indicated that products which had undergone over 70% of total melt were spreadable. Sensory assessments of spreadability correlated highly (r^2 = 0.94) with texturometer measures of firmness. The combination of sensory rate of mouthmelt data with texturometer firmness assessments added 3% to the prediction of spreadability.

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INTRODUCTION

The per capita consumption of margarine has almost doubled over the last 30 years while butter consumption has undergone a corresponding decrease (Figure 1). Much of the credit for the increasing popularity of margarine has been the ability of the oil processors to respond to consumer demands for improved performance characteristics (Wiedermann, 1968; Masseillo, 1980).

The performance characteristics which determine consumer acceptance of a food products are flavour and texture (Drake, 1974). Texture was defined by Sczcesniak (1963) as the appearance, mouthfeel and handling properties of a food product. The textural qualities important to a tablespread are spreadability (Haighton, 1965; Weiss, 1970; Prentice, 1972; Davis, 1973; deMan _et al_., 1979; Board _et al_., 1980) and mouthmelt (Anon, 1979; Bassett, 1979). It was suggested by Taylor and Norris (1977) that spreadability was the main textural advantage of margarine over butter. The textural qualities of all foods are a direct function of the chemical composition and molecular arrangement within the product (Drake, 1974). In tablespreads the fatty acid composition (FAC) is the primary determinant of texture; alteration of the FAC by hydrogenation changes the liquid oil to a semi-solid fat (Weiss, 1970).

The nutritional quality of a fat product is also determined by the FAC. A recent report by the ad hoc committee on the composition of special margarines to the Health Protection Branch, Canada included rec-

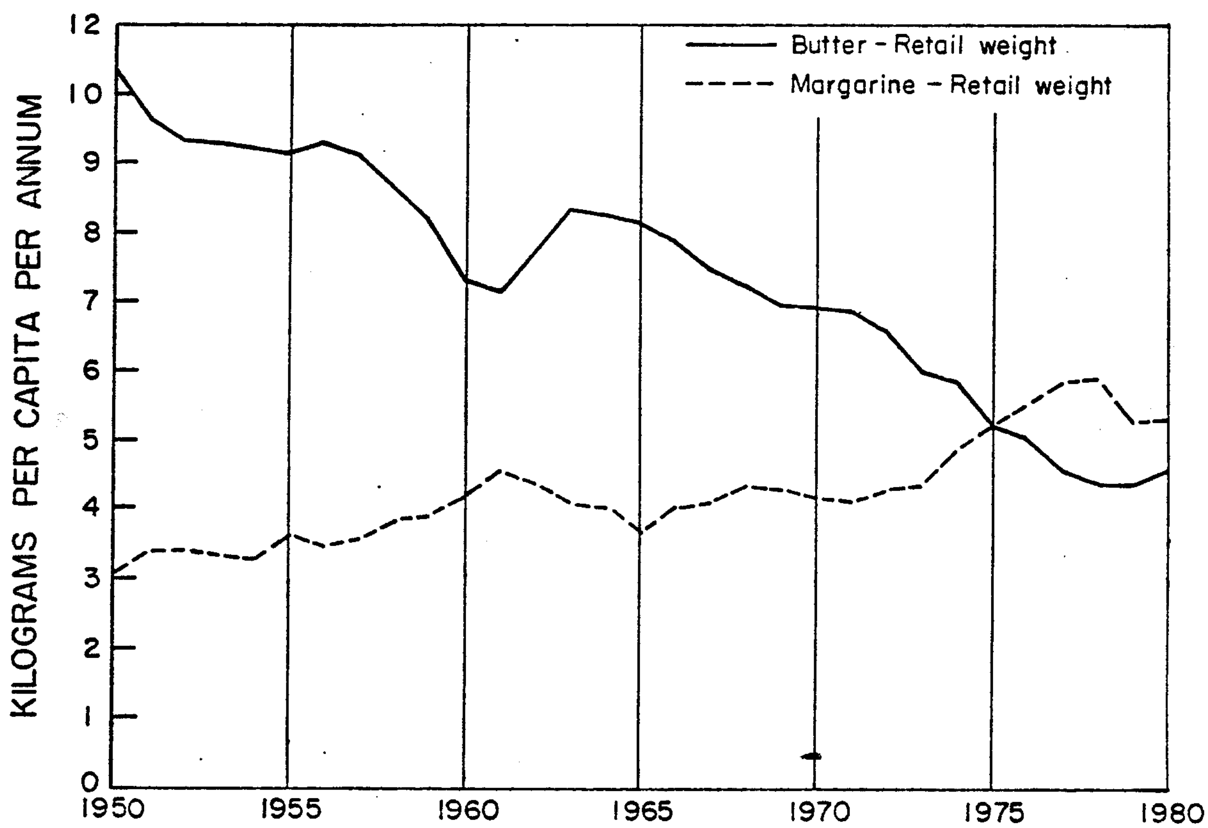


Figure 1: The Apparent Per Capita Consumption of Tablespreads in Canada - 1950 to 1980[1]

[1]Vaisey-Genser, 1981

ommendations that margarine and margarine-like products contain no less than 5%, by weight fat, cis,cis-6,9-octadecadienoic acid (cis-cis C18:2) and that a product contain at least 25% cis-cis C18:2 before a label claim be allowed; correspondingly the proportion of total saturated plus trans fatty acids should not exceed 40% (Davignon et al. 1980).

Since rapeseed oil was introduced as a food oil in the late 1940's there has been a steady increase in rapeseed's contribution to the edible oil market in Canada (Figure 2); there was a slight drop in production in the mid 1970's while new varieties of rapeseed, officially trademarked as canola in 1980 (Canola Council of Canada, 1981), came into production. For the year 1980, 31% of Canadian margarine oil, 68% of salad oil and 32% of shortening oils were canola (Statistics Canada, 1980). Canola is the major oilseed grown in Canada; other food oils are for the most part imported (Figure 3). The low share of canola in the production of margarines coupled with the fact that the other major margarine oil, soy, is mostly imported, suggests a market potential for canola oil thereby reducing national dependency on imported food oils.

The overall objective of this research was to define the textural qualities of margarine and butter; the secondary objective was to evaluate canola products in comparison to other vegetable oil margarines on the Canadian market.

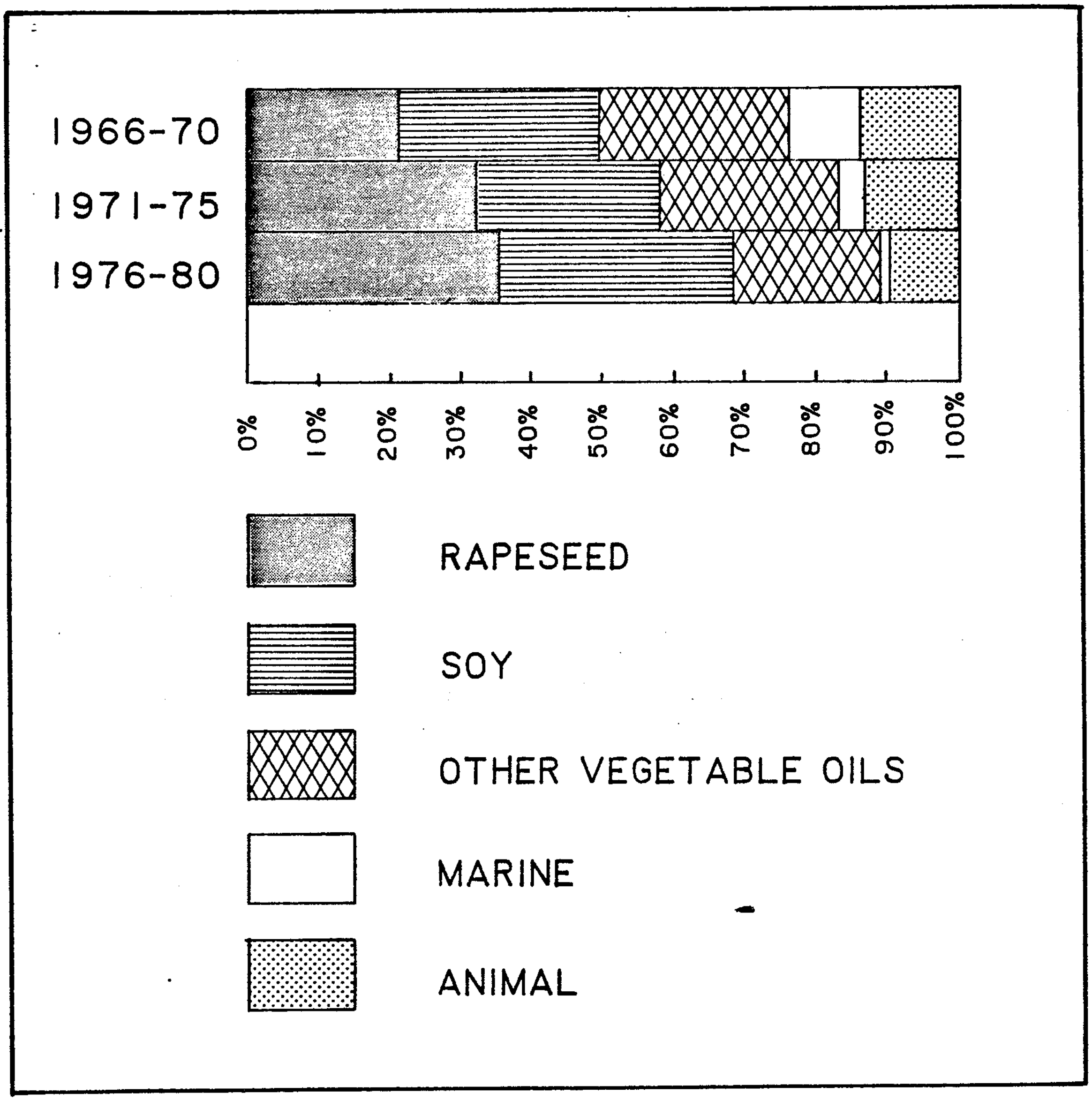
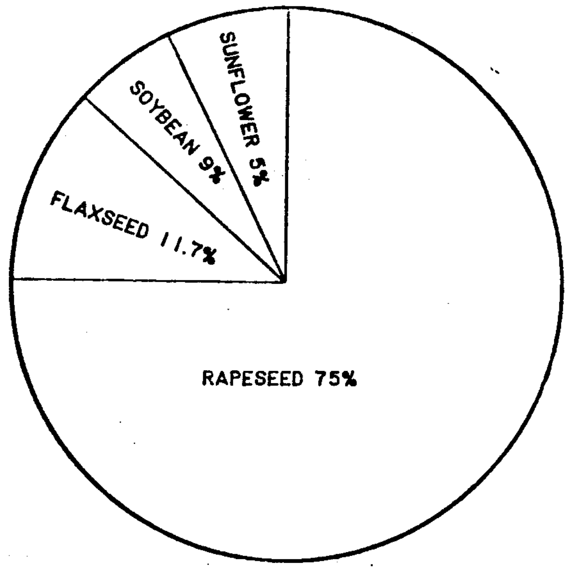


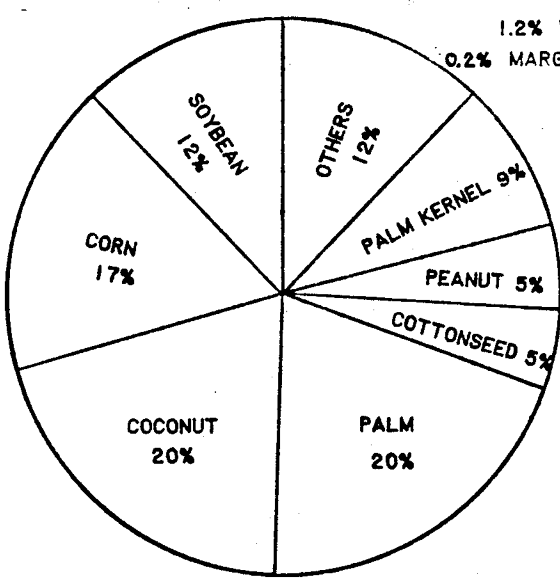
Figure 2: Importance of Rapeseed and Canola in the Canadian Edible Oil Market[1]

[1]Vaisey-Genser, 1981



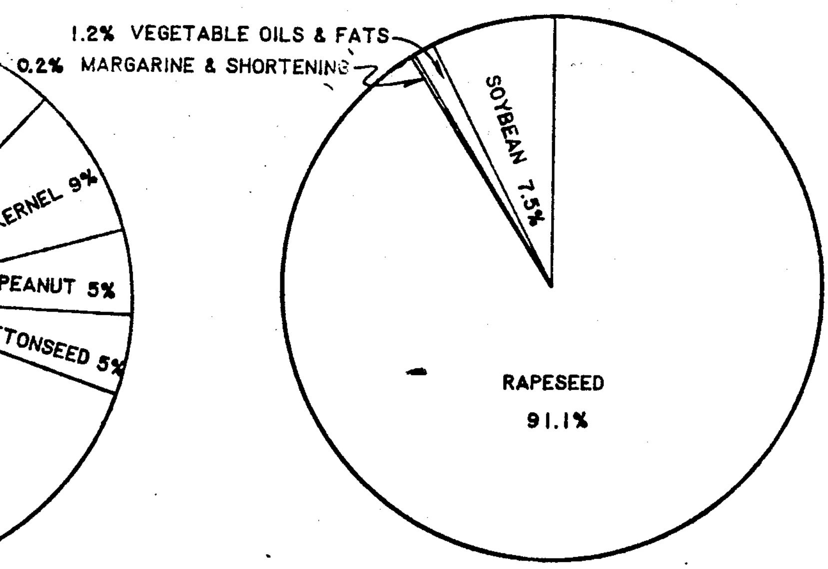
% OF CANADIAN OILSEED PRODUCTION (OIL EQUIVELENT)

TOTAL=1,409,411 TONNES.



% CANADIAN IMPORTS OF FATS AND OILS

TOTAL=100,235 TONNES



% EXPORT OF CANADIAN FATS AND OILS

TOTAL=189,519 TONNES

Figure 3: The Production and Import/Export of Edible oils in the Canadian Market in 1979[1]

[1] Grain Marketing Office, 1980

LITERATURE REVIEW

Chemical Composition

Margarine was described by Haighton (1976) as a water in oil emulsion: the oil phase existing in two states, solid crystals and liquid oil with attractive forces between the crystals conferring structural integrity to the product. The relative proportion of the solid to liquid in the continous phase coupled with the molecular arrangement of the solid crystals are the primary determinants of the physical properties of a tablespread. The proportion of solid fat, at any given temperature, depends on the melting points of the constituent fatty acids; in general melting point increases as chain length increases, the presence of double bonds lowers the melting point, and trans isomers have a higher melting point than the correspondng cis form (Table 1). The melting point of the triglyceride reflects the FAC of that molecule. As shown in Table 1, adding shorter, lower melting fatty acids progressively lowered the melting point by approximately 10°C. The effect of molecular arrangement on the physical properties results from polymorphic behavior of fat crystals. The three most commonly recognized forms are α, β' and β, listed in terms of increasing melting point (Table 1), size (Hoerr and Ziemba, 1963) and stability (Hanniwejk et al., 1964). Chapman (1962) characerized β crystals as having lower entropy and less molecular motion which allowed them to pack. He went on to explain that packing was more pronounced when fatty acids on the glyceride were homogene-

TABLE 1

Melting Points of Representative Fatty Acids and Triglycerides

		M.P. (°C)
Fatty Acids[1]:		
n-dodecanoic acid (C12:0)		44.2
n-hexadecanoic acid (C16:0)		62.7
n-octadecanoic acid (C18:0)		69.6
cis-9-octadecenoic acid (_cis_ C18:1)		10.5
trans-9-octadecenoic acid[2] (_trans_ C18:1)		44.0
cis,_cis_-9,12-octadecadienoic acid (_cis-cis_ C18:2)		-5.0
Triglycerides[3]:		
C18:0-C18:0-C18:0	α form	55.0
	β form	71.0
C18:0-C16:0-C16:0	α form	47.4
	β form	62.7
C18:0-C16:0-C12:0	α form	33.4
	β form	52.0

[1] Gurr and James, 1971
[2] Weiss, 1970
[3] Chapman, 1962

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		M.P. (°C)
Fatty Acids[1]:		
n-dodecanoic acid (C12:0)		44.2
n-hexadecanoic acid (C16:0)		62.7
n-octadecanoic acid (C18:0)		69.6
cis-9-octadecenoic acid (*cis* C18:1)		10.5
trans-9-octadecenoic acid[2] (*trans* C18:1)		44.0
cis,*cis*-9,12-octadecadienoic acid (*cis*-*cis* C18:2)		-5.0
Triglycerides[3]:		
C18:0-C18:0-C18:0	α form	55.0
	β form	71.0
C18:0-C16:0-C16:0	α form	47.4
	β form	62.7
C18:0-C16:0-C12:0	α form	33.4
	β form	52.0

[1] Gurr and James, 1971
[2] Weiss, 1970
[3] Chapman, 1962

ous in chain length and that trans double bonds facilitated packing because of the similarity in structure to the saturated counterpart. However, triglycerides containing both short and long chain fatty acids had unusual α stability. Agglomeration of the β crystals into discrete particles has been identified as the cause of coarse texture or graininess, a problem not uncommon in some margarines (Merker et al. 1958; Wiedermann, 1968) and recently identified in canola products (deMan, 1978; Persmark and Bengtsson, 1976; Loewen, 1980).

The original rapeseed oils were characterized by high levels, often exceeding 20%, of cis-13-docosenoic acid (C22:1) a fatty acid characteristic of Cruciferae. Nutritional studies on rapeseed oil implicated C22:1 as a potential health hazard (Beare-Rogers, 1977). Plant breeding programs at the University of Manitoba and Agriculture Canada during the 1960's developed new cultivars of rapeseed, now called canola; the major change in the oil was the reduction of C22:1 to less than 5% (Table 2). The reduction of C22:1 had the effect of causing a corresponding increase in the C18 fraction, especially C18:1 (Weinberg, 1972); comparison of canola oil with other vegetable oils showed a relatively low amount of C18:2 and also twice as much C18:1 as in corn, soy and sunflower oils. Weinberg (1972) anticipated that the high levels of the C18:1 fraction and the low level of C16:0 would cause texture problems for the new canola products by providing a homogeneous fatty acid composition. Butter has approximately 20% short and medium chain fatty acids and 3% C16:1 which were not shown in Table 2, this combined with the low levels of long chain fatty acids make it distinctive from vegetable oils.

TABLE 2

Relative Composition of Selected Fatty Acids (w/w%) in Vegetable Oils and Butter Fat

Fatty Acid	Rapeseed Target[1]	Canola Oro[1]	Corn[2]	Soy[2]	Sunflower[2]	Palm[2]	Butter Fat[3]
C16:0	5.1	5.0	11.5	10.5	7.0	46.8	38
C18:0	1.3	0.9	2.2	3.2	3.3	3.8	9
C18:1	23.5	62.8	26.6	22.3	14.3	37.6	19
C18:2	16.6	19.5	58.7	54.5	75.4	10.0	2
C18:3	9.1	9.2	0.8	8.3	-	-	-
C20:1	12.5	2.0	-	-	-	-	-
C22:1	32.1	0.7	-	-	-	-	-

[1] Weinberg, 1972
[2] Weiss, 1970
[3] Gurr and James, 1971

Physical Properties

The textural parameters of tablespreads, spreadability and mouthmelt, are both dependent on the amount of solid fraction present. For a product to be spreadable it must be plastic across a wide temperature range, but the sensation of mouthmelt implies that the solid fraction remaining at body temperature melt quickly. The standard quality control assessment used by industry on a margarine oil to predict the textural properties has been the Solid Fat Index (SFI) (Hannewijk, et al., 1964; Weiss, 1970; Haighton, 1976). SFI, as a statement of solid fat content, has been measured by dilatometry (AOCS Standard Method CD 10-57) since the 1920's; the method is based on the fact that the change in state from solid to liquid involves an increase in volume (Hannewijk, et al., 1964).

Weiss (1970) discussed SFI in terms of functionality with reference to typical values reported by Wiedermann (1968) (Table 3). It was suggested that a SFI value of less than 28 at any temperature would be necessary for spreadablity, greater than 30 would result in a hard brittle product; no lower limit for spreadability was recommended. The SFI at 33.3°C was felt to correlate well with mouthmelt; a value of approximately 3.5 was required to a achieve a melt sensation. Comparison of the SFI values for the brick and tub margarines in Table 3 suggested that the brick product may have been difficult to spread at refrigerator temperatures, but that the tub would be spreadable; there would have been little difference between the two regarding mouthmelt. The bakers' product displayed a consistent solids content across the temperature

TABLE 3

Typical SFI Values for U.S. Margarines[1]

	Temperature (°C)			
Margarine Type	10	21.1	33.3	37.8
Brick	28	16	2-3	0
Tub	13	8	2	0
Bakers'	27	18	12	8

[1] Weiderman, 1968

range providing the plasticity necessary for its function, however, it would have had a poor mouthmelt sensation and left a waxy mouth coat.

DeMan *et al.* (1979) compared sensory panel assessments of spreadability with the solid fat indices of products available on the retail market in Canada. The panel found that products with SFI values between 10 and 20 across all temperatures were ideally spreadable, the average SFI of products judged too hard to spread was 34.7 and too soft to spread 7.1. It was observed that the ten member panel in deMan *et al.*, (1979) preferred a somewhat softer product than Weiss (1970) had expected almost a decade before. This may indicate a trend of consumer preference for softer products.

Dilatometry is performed on anyhdrous oil samples under carefully defined cooling and holding conditions to standardize crystallinity, therefore crystal polymorphism cannot be predicted. This problem was illustrated by Haighton (1976); the firmness of one fat was found to be five times greater than the firmness of a second fat with an identical SFI as a result of large interlocking crystals in the first product.

The use of differential scanning calorimetry (DSC) has been explored by a number of researchers as an alternate procedure for obtaining SFI (Bentz and Breidenbach, 1969; Miller *et al.*, 1969; Walker and Bosin, 1971; Norris and Taylor, 1977). DSC measures the heat of fusion for a substance by plotting the endothermic and exothermic heat exchange between the sample and the sample cell. For the melt thermogram an endothermic heat exchange would indicate that the sample was absorbing heat, thereby undergoing a change of state. By comparing the energy absorption prior to a specific temperature to the total energy required for melt, the solids remaining at the specific temperature would be estimated. Unfortunately the method did not correlate well with SFI as determined by dilatometry and was less precise; even so the authors (Bentz and Breidenbach, 1969; Miller et al., 1969; Walker and Bosin, 1971) concluded that the rapidity of the method and the distinctive melt pattern produced for each product justified the use of DSC as a quality control method and urged the American Oil Chemists Society to standardize the technique. Norris and Taylor (1977) explained that the poor correlation between DSC and dilatometry values for SFI resulted from the assumption that heat of fusion is constant; the value used was 35 cal/g, whereas the heat of fusion increases with melting point.

Taylor and Norris (1977) and deMan et al., (1979) used DSC melt thermograms to explain successfully the difference in spreadability observed among tablespread products (Figure 4). Butter oil had little or no melt below 0°C which explained the firmness of butter at refrigerator temperatures; the margarine oil from the tub products had considerable melt below 0°C which ensured a lower solids content and better spreadability at the lower temperatures; the brick margarine oil displayed properties intermediate between the butter and tubs. Butter displayed a major portion of melt between 0°C and 20°C which made it soft at the higher temperature, the brick margarine oil melted enough to make the product spreadable at 20°C, the tub oil had relatively little melt thus maintaining its structural integrity. It is difficult to extrapolate information from the figures presented regarding mouthmelt since neither group reported area measurements or partial heats of fusion.

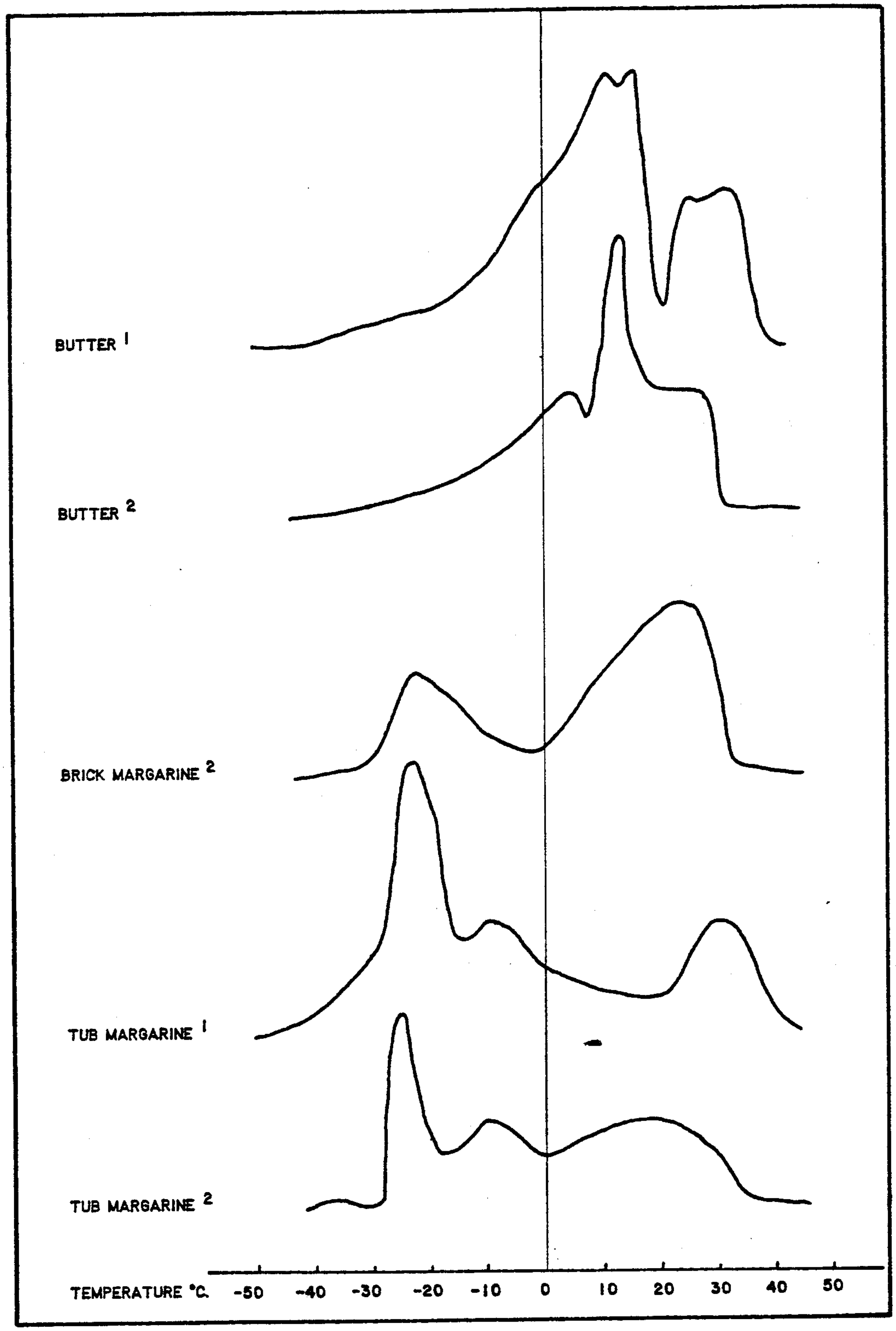

Figure 4: DSC Melt Thermograms of Tablespread Oils

[1]Taylor and Norris, 1977
[2]deMan *et al*., 1979

The DSC research reported so far on tablespreads used anhydrous oil samples with controlled crystallization, therefore did not overcome the basic limitation of dilatometry which is that it can not predict the crystal effects in the final product. Sherbon and Dolby (1971) compared thermograms of isolated butter fat and serum with the thermogram of the corresponding butter which was loaded unmelted (Figure 5). Although the salt/water melt masked the fat melt below 0°C, comparisons above 0°C were considered valid. The differences between the fat and the butter suggested that thermograms of a solid fat in market form would provide useful information about the product as used by the consumer.

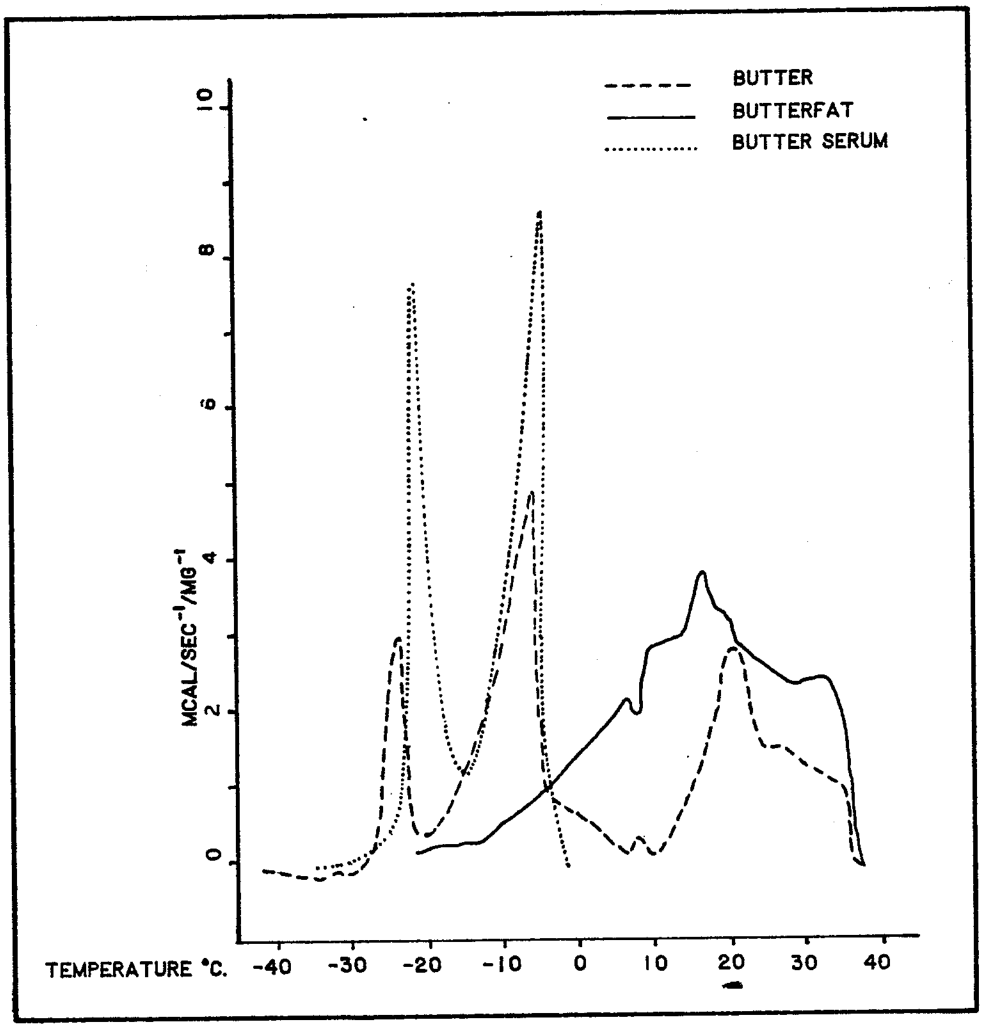

Figure 5: DSC Thermograms of Butter, Butter Fat and Butter Serum[1]

[1]Sherbon and Dolby, 1971

Textural Assessments

Haighton (1959) advocated that a yield value obtained by cone penetration was an adequate predictor of spreadability and developed quidelines for interpreting cone penetrometer values (Table 4). No information regarding the sensory evaluations was provided. Yield values of 200-800 (g/cm^2) were recommended for an ideally spreadable product; firmness values of less that 100 were felt to be too soft to be spreadable.

Reseach by deMan et al., (1979), Dixon and Parekh (1979) and Board et al. (1980) used the penetration principle and correlated hardness, cone stress index and single pin maturation readings, respectively, with sensory panel assessments of spreadability. The different instruments and the units in which hardness was expressed made absolute comparisons among studies impossible. DeMan et al. (1979) used cone penetration and reported hardness, g/cm^2, of tub and brick margarines and butter commercially available in Canada. The ten member trained panel spread the products on crackers and scored spreadability on a 9-point scale from 9 - extremely hard, 5 - ideally spreadable to 1 - extremely soft; the assumption that firmness was analogous to spreadability was implied. Testing was done at 5, 10, 15, 20 and 25°C. The results (Figure 6) showed that a wide range of hardness, approximately 100 to 725 g/cm^2 was considered spreadable. While the incomplete block design used did not allow for testing of the panelist effect, the range of hardness values within each sensory rating suggests that panelists had different spreadability criteria. The correlation coefficient of the sensory and the penetrometer values was 0.76; although this was reported

TABLE 4

Interpretation of Cone Penetration Yield Values by Thumb Assessments of Spreadability[1]

Yield Value (g/cm^2)	Assessment
< 50	Very soft, to just pourable
50-100	Very soft, not spreadable
100-200	Soft, but already spreadable
200-800	Satisfactory plastic and spreadable
800-1,000	Hard, but satisfactorily spreadable
1,000-1,500	Too hard, limit of spreadability
> 1,500	Too hard

[1]Haighton, 1959

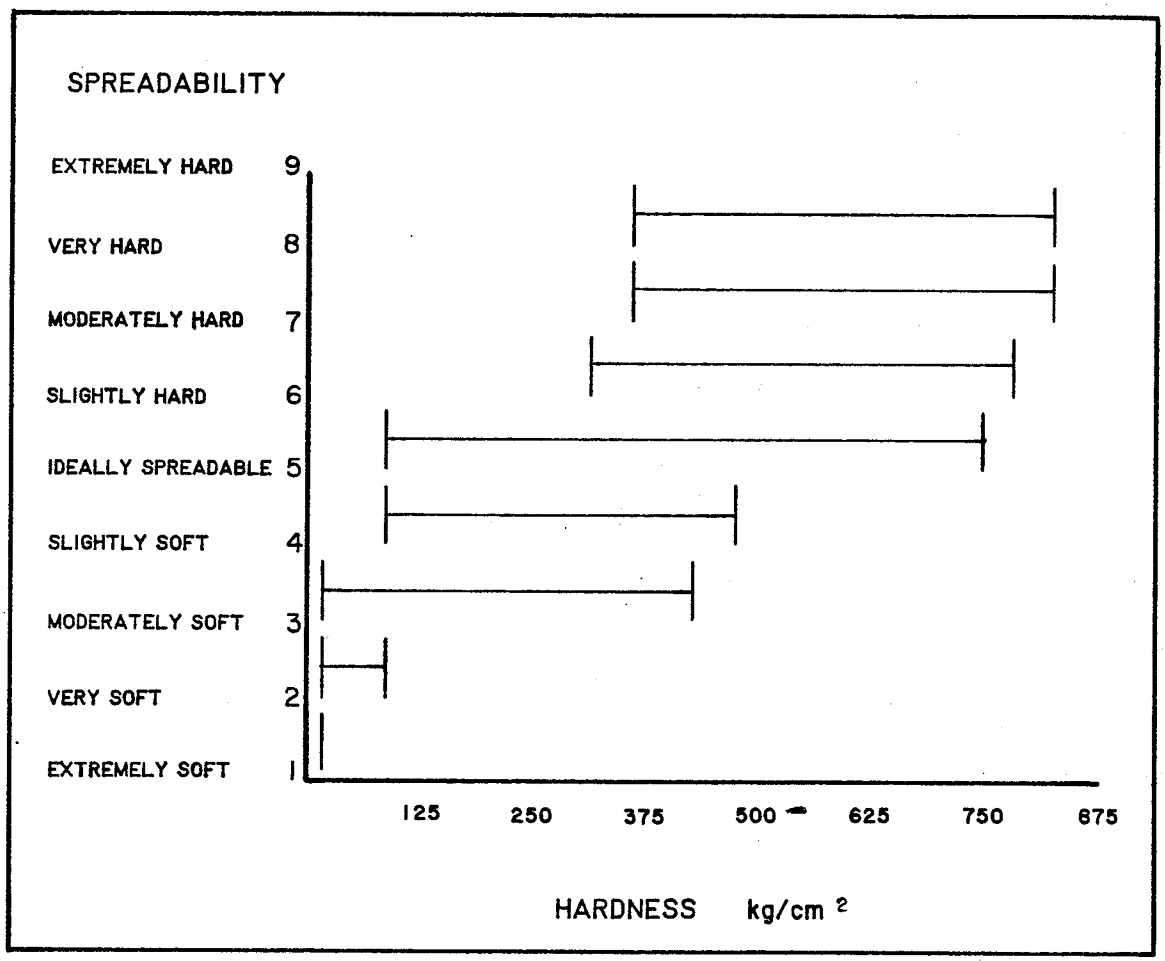

Figure 6: Range of Hardness Values Included in Each Sensory Rating of Spreadability[1]

[1] adapted from deMan et al., 1979

as being highly significant it meant that only 58% of spreadability could be predicted from the hardness assessment. In general the tub margarines and a few of the brick margarines were considered spreadable at 5°C, the brick margarines and butter were considered spreadable at 20°C, the tubs at 20°C were scored in the slightly soft to very soft range; by 25°C all the products except one brick were in the soft range, scoring less than 4 with one tub scoring extremely soft, less than 1. Butter displayed a strong temperature interaction, it was the hardest product at 5°C but one of the softest at 25°C.

The next two studies reported used Australian products. Dixon and Parekh (1979) compared commercial butter and experimental soft butters using a cone stress index from cone penetration. Sensory analysis was performed by laboratory staff spreading the products on bread and scoring spreadability on a 15 cm line scale. The line scale had three markings 1 - sloppy, 7 - spreadable and 14 - hard. Test temperatures were 5, 13 and 20°C and results were pooled. The authors found there was good agreement among panelists when firmer products were scored but large variation arose for softer products; three of the four panelists hesitated to assign scores of less than spreadable to the soft products which were therefore omitted from the analysis. The relationship (Figure 7 a) had a correlation coefficient of 0.97.

Board _et al_. (1980) obtained single pin maturometer values for commercial tub and brick margarines and butters and compared these with panel spreadability scored on a 7-point scale. The end points on the scale were 1, extremely poor to 7, extremely good; the twenty experienced but untrained panelists were reminded that extremely soft and hard

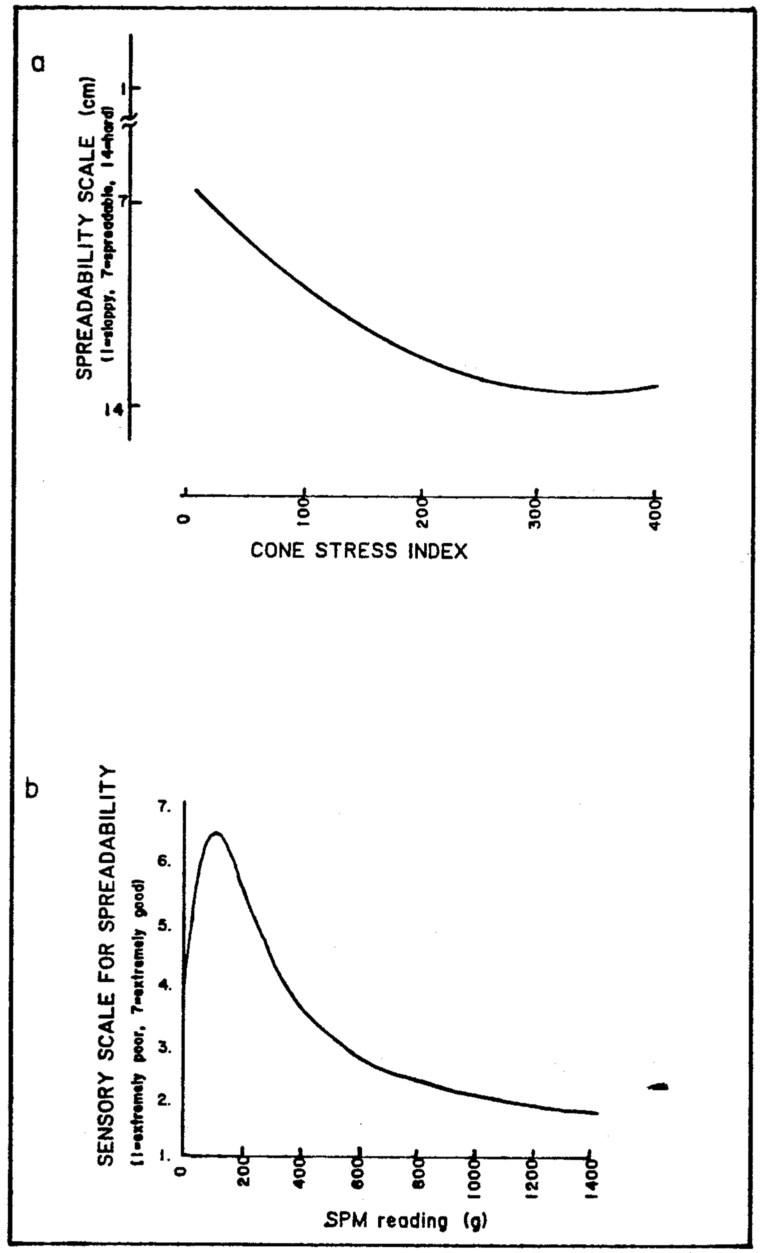

Figure 7: Hardness Values Obtained by Different Methods of Penetration Related to Panel Assessment of Spreadability

a Dixon and Parekh, 1979
b Board et al., 1980

products would receive a low score. Panelists again spread the products on bread and all testing was performed at 22°C. As in the previous study panelists were reluctant to score soft products as poorly spreadable (Figure 7 b). The tub margarines and many of the bricks and butters were spreadable at 22°C with maturometer readings of 20-200 g; some brick margarines and butters with readings of greater than 600 g were approaching poor spreadability on the firmness side, even at 22°C. The hardness of the products was unusual because the samples were loaded into sample containers for the single pin penetration test thus structural disruption would have occurred; the samples were allowed 24 hours for recovery but it has been observed by other researchers that tablespread products never fully recover their initial hardness after being worked (deMan, 1969).

The Consumers Union reported sensory panel assessments of spreadability of American commercially available products; no corresponding penetration tests were performed (Anon, 1979). Samples of the brick margarines were presented as cubes equal to one tablespoon, tub margarines were presented as a level tablespoon; samples and bread were removed from the refrigerator and warmed to room temperature for 30 minutes before testing. Products were scored from 1 to 5, soft to hard (Figure 8), the amount required to cover the slice of bread was also measured. The analogy of firmness with spreadability was again evident and the use of the term 'normal' is arbitrary. The authors implied the assumption that softer was better in terms of spreadability by saying 'very easily spread' however the 'amount to cover' of such a product was 'too thin a layer'. In agreement with deMan et al. (1979) and Board et

SPREADABILITY

Score	Descriptor
1	very soft, very easily spread, no resistance, oily
2	soft, easily spread, little pressure required
3	normal
4	poor spreadability, uneven spread, lumpy
5	very difficult

AMOUNT TO COVER

Measure	Descriptor
1/4 Tbsp.	too thin layer, covers entire slice
1/2 "	easy coverage
3/4 "	normal, covers evenly firmly
1 "	too thick a quantity

Figure 8: Scoring System for Consumers Union Assessments of Tablespreads[1]

[1]Anon, 1980

al. (1980), the tub products were the most spreadable while the brick products were the most difficult to spread; in addition it required 3/4 to 1 tablespoon of brick margarine to cover the bread but only 1/4 to 1/2 tablespoon of tub margarine.

Although the above studies which compared penetration with panel spreadability assessments showed good agreement between the methods, Wiedermann (1968) argued that spreadability is a dynamic property and that penetration, a static test, was not adequate to predict sensory spreadability. He defined spreadability as the rate of deformation when external pressure was applied. The danger of using a single determinator for prediction was illustrated as follows (Figure 9); A and B were hypothetical responses of two fat products to stress, if pressure x was applied the conclusion that the two fats were equal in hardness would be made, however if a pressure less than x was applied B product would be considered softer than A and vice versa for a pressure greater than x.

Haighton (1965) recognized the problem when he observed that consumers found margarine more spreadable than butter even when the two products had equal hardness when assessed by cone penetration. No details on the consumer assessment were available. Haighton (1965) added a work softening factor to his predictability equation:

$$S.I. = Hi - 0.75\ (Hi - Hw)$$

The Spreadability Index (S.I.) was thus a function of the initial hardness (Hi) and the hardness after the product had received a fixed amount of work (Hw). The correlation coefficient of spreadability with the S.I. was reported to be 0.95. Haighton (1965) found that margarine decreased in hardness by 75% when worked but that butter decreased only

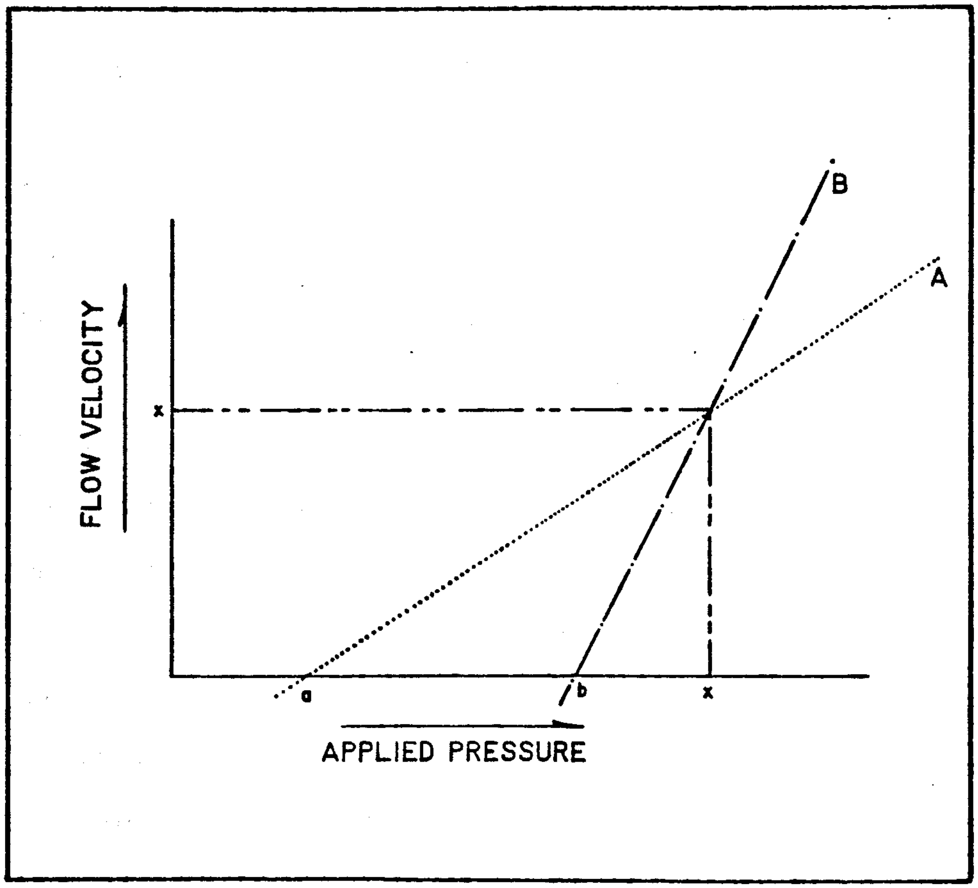

Figure 9: Consistency Curves of Two Fats Illustrating the Problem with a Single Determination of Hardness[1]

[1] Wiedermann, 1968

50%; this difference in resistance to work was felt to explain the anomaly in the spreadility assessments of the two products. Shama and Sherman (1970) using a parallel plate viscoelastometer also observed that when worked, margarine underwent much greater structural alteration than did butter.

The difference in hardness before working and after working is theoretically related to the type of bonding within the solid fat phase; weak, secondary Van der Waals forces rupture but reform readily, providing thixotropy; primary bonds between crystals resist disruption, providing initial hardness, but once ruptured do not reform readily leaving the product structurally weakened. The relative amounts of primary and secondary bonding therefore determine product response to stress (van den Temple, 1958; Haighton, 1965; Shama and Sherman, 1970; Yaron et al., 1975). Margarines are generally considered to be viscoelastic (deMan, 1976); the model (Figure 10) shows the response of a product to stress, at t2 the product yielded to the stress and exhibited viscous flow, when the stress was removed at t3 there was elastic but incomplete recovery. The extent of recovery was dependent on the amount of stress and the length of application of the stress, therefore dependent on the extent of primary bond rupture.

The General Foods texturometer was designed to present simultaneously most of the parameters necessary to make a complete description of texture (Figure 11 a). Hardness is obtained from the height of the first peak which shows the force required to cause deformation of the sample; cohesiveness, the force required to overcome internal bonding, is represented by the ratio of area 2 over area 1 and adhesiveness, area

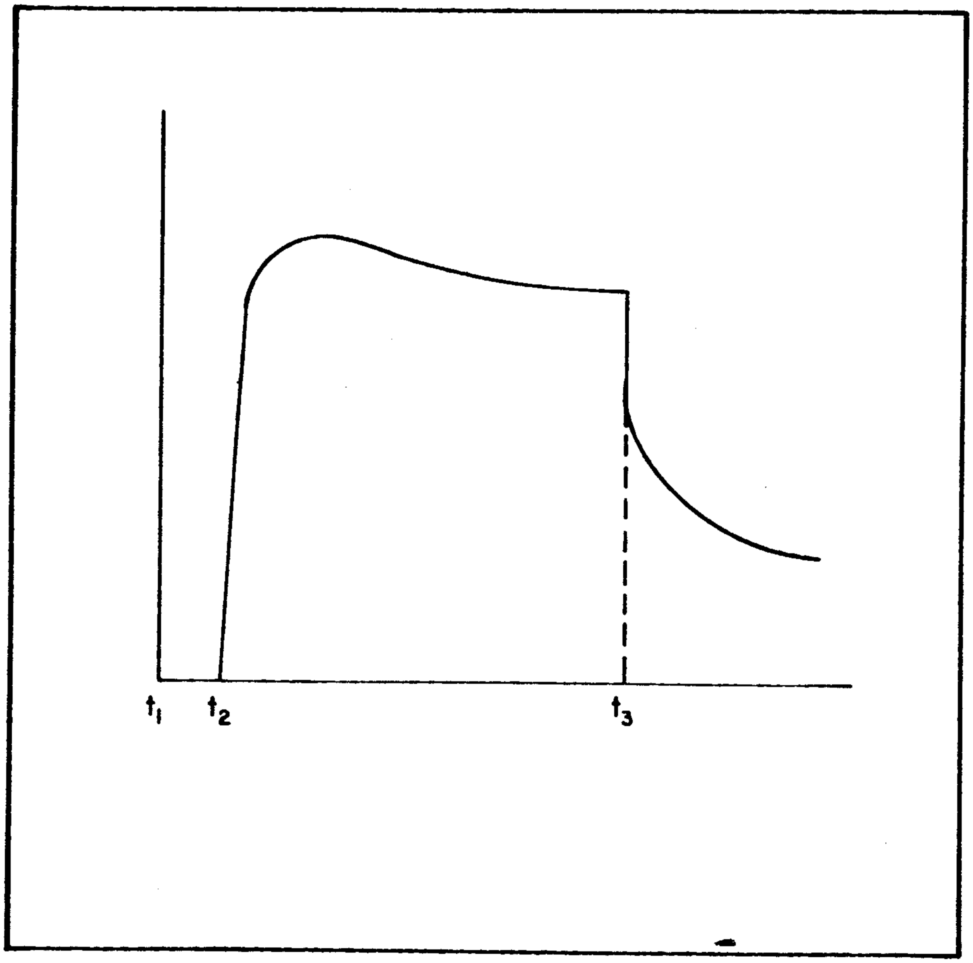

Figure 10: Model for Viscoelastic Behavior of Tablespreads

[1]Vocadlo and Moo Young, (1969)

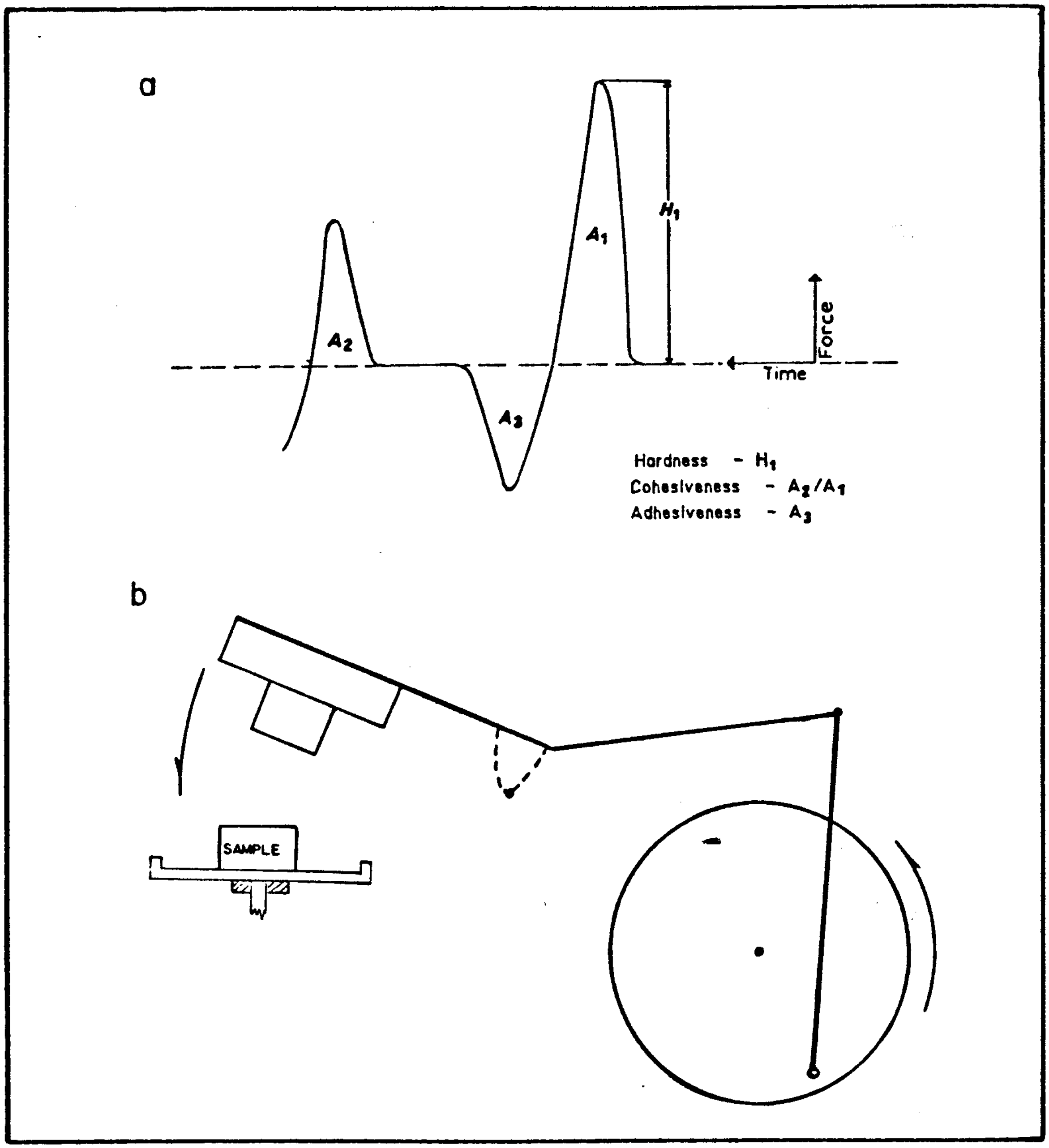

Figure 11: Interpretation of the Texturometer Curve[1] and the Action of the Plunger[2]

[1]Brennan et al. 1970

[2]Brennan et al. 1975

3, is the force required to separate the plunger from the sample. Parameters such as gumminess and chewiness were not directly relevant to this study. The arculate movement of the plunger (Figure 11 b) could be preceived as approximating a spreading motion.

The literature on tablespreads had dealt mainly with assessments of firmness and with defining the rheology of fats; very little was available which measured the mouthfeel sensations of melt or graininess. The report on tablespreads by the Consumers Union (Anon, 1979) mentioned that mouthmelt was the major defect for the mouthfeel properties of margarines. The problems arose with whipped and diet products which were generally slow melting or had uneven melt, forming curds; the latter was likely a function of the high water content and a poor emulsion. Regular tub and brick margarines occasionally received criticism for being slow to melt or having an oily or greasy mouthfeel or a slightly chalky texture.

The main concern regarding the use of canola oil in margarines has been the reported tendency for the products to develop a grainy, unacceptable texture on storage (Teasdale et al, 1970; Teasdale, 1975; deMan, 1978). Teasdale (1975) stated that it was not possible to produce 100% canola based margarines because of this problem. No assessments of the sensory response to graininess in margarines has been reported however.

Objectives

The present research evaluated butter and margarines, the major vegetable oil sources of which were canola, corn, soy and sunflower, by:

1. obtaining the fatty acid composition by gas liquid chromatography (GLC);

2. describing the physical properties in terms of SFI and DSC melt thermograms;

3. defining the textural characteristics of firmness, work to soften, spreadability, rate of mouthmelt and graininess using a sensory panel;

4. obtaining texturometer assessments of firmness and work to soften and relating these to the sensory assessments;

5. describing the effect of temperature on the textural parameters;

6. providing insight into the effect of oil species and market form on textural characteristics;

7. testing the effect of storage on the textural quality of canola products.

EXPERIMENTAL DESIGN

The chemical and physical characteristics which were defined by the fatty acid composition, solid fat content and melting properties were used to explain the textural characteristics of tablespread which were obtained by sensory panel and texturometer assessments. The textural parameters were classified as mechanical: firmness, work to soften and spreadability; and mouthfeel: rate of mouthmelt and graininess. Both sensory and texturometer assessments of firmness and work to soften, and sensory rate of mouthmelt were incorporated into multiple regression statements to develop predictive equations for sensory spreadability.

In general, textural assessments were performed on 12 tablespreads, 11 margarines and butter, at two temperatures, 4°C (refrigerator temperature) and 21°C (room temperature) in a factorial arrangement. The selection of tablespreads allowed post hoc comparisons of oil source, market form and storage effects (Figure 12). The design was confounded by manufacturer effect, since products of each oil source were not obtained from the same supplier.

Comparisons among oil sources were performed separately on brick and tub market forms; the values for canola bricks from both manufacturers were pooled for the comparison and the fresh canola products were omitted to control for aging effects. Therefore oil source comparisons were made among five oil species in the brick group and four in the tub group as outlined in Figure 12. The fresh canola products, the canola

SPREAD TREATMENT	OIL SOURCE	MARKET FORM	MANUFACTURER	STORAGE CONDITION
1	canola	brick	I	Stored
2	canola	brick	I	Fresh
3	canola	brick	II	Stored
4	canola	tub	I	Stored
5	canola	tub	I	Fresh
6	corn	brick	II	Stored
7	corn	tub	II	"
8	soy	brick	II	"
9	soy	tub	II	"
10	sunflower	tub	III	"
11	sunflower	brick	III	"
12	butter	brick	IV	Fresh

POST HOC COMPARISONS

Effect	Treatment	
Oil Source	Brick	Tub
	butter (12)	canola (4)
	canola (1+3)	corn (7)
	corn (6)	soy (9)
	soy (8)	sunflower (11)
	sunflower (10)	
Market Form	brick (1+6+8+10)	
	tub (4+7+9+11)	
Storage	stored (1+4)	
	fresh (2+5)	

Figure 12: Experimental Design of Tablespread Texture Study

brick product from manufacturer II and butter were omitted from the comparisons between brick and tub market forms; the mean values for both brick and tub were obtained by pooling four treatment means (Figure 12). The storage effect was tested only between fresh and stored canola products from manufacturer 1. No testing was done on the manufacturer effect.

The sequence in which the tests were performed is outlined in Figure 13. The initial products, received month 1 to month 6 of the study were included in all tests. Products were stored in a walk-in refrigerator until sampling. Two fresh canola products from manufacturer 1 were added in month 12 therefore the storage effect on canola products could only be tested in the sensory assessment of mouthfeel properties and in the texturometer assessments. Comparisons among treatments were weakened by the confounding of the manufacturer effect and the differing ages of the products; the relationship among the various tests was weakened by the time sequence in which they were performed.

Departures from these basic procedures and details relevant to each test are included in the methods.

MONTH OF STUDY	PROGRESS	TESTING METHOD
1	Solid fat content of canola I - brick, tub & butter	Solid Fat Index
2	Products received - Manufacturer II	
	Products received - Manufacturer I	
6	Products received - Manufacturer III	
	Melting properties of all products obtained	Differential Scanning Calorimetry
11-12	Sensory analysis - mechanical properties	Magnitude Estimation
	Fresh products received - Manufacturer I	
	Sensory analysis - mouthfeel properties	Time (seconds) & Line Scale
13-14	Fatty acid composition & <u>trans</u> fatty acids	Gas Liquid Chromatography
16	Texturometer assessment of texture	General Foods Texturometer
	Melting properties of canola I brick - rerun	Differential Scanning Calorimetry
18	% <u>trans</u> fatty acids	Infrared

Figure 13: Time Line of Tablespread Texture Study

MATERIALS

Margarine samples were brand name, commercially available products; supplied directly from the manufacturer. Details from the product labels are included in Appendix A. Butter was purchased as needed from local retail outlets. Chemicals were reagent grade; all other materials and equipment are described in the methods.

METHODS

Fatty Acid Composition

Fatty acid patterns and % trans fatty acids of all products were determined with a 1740 Varian aerograph gas liquid chromatograph (GLC) equipped with dual flame ionization detectors and a Hewlett-Packard Model 3380-S recording integrator. Two fatty acid samples for each margarine product were methylated using boron trifluoride according to the method of Metcalfe et al. (1966). Fatty acid composition was analyzed on an 8 ft. by 1/8 in. stainless steel column packed with 3% SP 2310/2% SP-2300 on 100/120 Chromosorb W AW (SP column), carrier gas flow rate was 30 ml/min. A two minute delay temperature program from 190°C-220°C at 2°C/min. was used.

Trans isomers were determined using a 20 ft. by 1/8 in. stainless steel column packed with 15% OV-275 on 100/120 Chromosorb P AW-DMCS (OV column). The runs were isothermal at 220°C, carrier gas flow rate was 10 ml/min (Ottenstein, et al., 1977). For both columns the injector port temperature was 230°C, detector port temperature 250°C, air and hydrogen flow rates were 250 ml and 25 ml/ min. respectively.

The amount of trans isomerization in each product was also analyzed by infrared spectrophotometry (IR) using the method of Beare-Rogers et al. (1979). IR values were adjusted to % fat assuming 80% fat in each tablespread.

Calculations of Total Trans Fatty Acids from GLC

The OV column values were first corrected for the loss of the long chain fatty acids. Using the corrected values total *trans* fatty acids were calculated by two methods to obtain minimum and maximum *trans* values as follows:

Method 1: min = *trans* C18:1 + *cis-trans,trans-cis* C18:2

Method 2: max = *trans* C18:1 + (Total C:18:2 - *cis-cis* C18:2)

Method 1 involved adding the values for *trans* C18:1 to those for *cis-trans*, *trans-cis* C18:2 from the OV column and assumed that no other *trans* fatty acids were present, probably underestimating *trans* content. Method 2 involved adding *trans* C18:1 values from the OV column to the difference between total C18:2 (SP column) and *cis-cis* C18:2 (OV column), thus assuming that all C18:2 other than *cis-cis* was *trans* and probably overestimated *trans* content.

Physical Properties

Solid Fat Index (SFI)

Solid fat indices on butter, canola I brick and canola tub were obtained by dilatometry using the AOCS Standard Method Cd 10-57 (1979). Canada Packers, Winnipeg Lab, provided technical assistance and access to their laboratory facility. SFI of the canola II brick, and the corn, soy and sunflower products were obtained from the manufacturers.

Differential Scanning Calorimetry (DSC)

Melting curves of all products were recorded with a DuPont 990 thermal analyzer. The Department of Food Science, University of Manitoba provided the equipment and technical assisstance. Samples of 9.00-12.00 mg of tablespread were weighed into sample pans immediately upon removal from the freezer. Two curves were obtained during a single run according to the method of Sherbon and Dolby (1972). The heating rate was 5°C/min. All samples were run against an aluminum standard. The canola 1 brick product was rerun after 11 months storage to see if crystal changes could be monitored by this method. A cross section of samples was run against a corn tub margarine as a preliminary investigation of the merits of such a comparison; the results were unsuccessful, small differences between the sample weight and the reference weight and differing salt levels obscured the sample differences.

The energy input (mcal/mg tablespread) during four stages of melt: below 4°C, 4°C-21°C, 21°C-33°C and residual, 33°C to end of melt, was calculated according to the formula from the instruction manual provided with the instrument (Figure 14). Areas were measured in square inches using a Gelman compensating plain polarimeter. The areas of melt were expected to be useful in explaining textural differences among spreads; the melt occuring before 4°C would reflect the stucture of the product at refrigerator temperatures, the area between 4°C and 21°C would predict the structural integrity of the product in this range and the melt occurring after 33°C could relate to the mouthmelt sensation.

Market form and oil source effects on the energy used for melt in each melt range were tested by a two factor analysis of variance.

$$\Delta H = \frac{60\ A\ b\ E\ \Delta qs}{m}$$

where: ΔH = mcal/mg sample

60 = conversion from seconds to minutes

A = area under curve in square inches

b = time base (2 min/in)

E = calibration coefficient (1)

Δqs = Y axis sensitivity, mcal/sec/in (0.5)

m = sample weight in mg

Figure 14: Calculation of Energy Uptake from DSC Melt Thermograms of Iablespreads

Butter and canola II, each having no corresponding tub market form, were omitted from the analysis to balance the design. Significant oil source effects were then tested using Duncan's multiple range test. Lack of replications of the earlier and later run of the Canola I brick made statistical analysis of the storage effect impossible.

Textural Assessment

Sensory Testing

The sensory methods used in the textural evaluation of tablespreads are outlined in Table 5. References were provided for the evaluation of the mechanical properties for which magnitude estimation was used as the measurement scale. The reference for the firmness assessment was presented at the same temperature as the samples, therefore no comparisons between temperatures were possible for this parameter. Stopwatches were provided to time the rate of mouthmelt; graininess was assessed using line scales (Larmond, 1977). Standardization of the magnitude estimation scores was performed using techniques discussed by Moskowitz (1977); details of these techniques are included in each method.

Samples for the assessment of the mechanical parameters were presented as 2 cm diameter balls, formed using a melon baller. Time to melt samples were presented as 1 ml measured amounts; samples for graininess were levelled in white plastic teaspoons. Samples for one complete evaluation of all samples were prepared at one time and stored at 4°C until tested. Samples for room temperature testing were left at 21°C at least 30 minutes prior to testing as preliminary investigations with a potentiometer had indicated that samples would be warmed within

TABLE 5

Outline of Sensory Testing Methods for Textural Assessment of Tablespreads at Each of Two Temperature Conditions

	TEXTURAL PARAMETER					
	MECHANICAL				MOUTHFEEL	
	FIRMNESS 21°C	FIRMNESS 4°C	WORK TO SOFTEN	SPREADABILITY	RATE OF MOUTH MELT	GRAININESS
REFERENCE	corn brick, same temperature as samples		vaseline (60%) -corn starch(40%) at room temperature	first sample random	none	none
MEASUREMENT SCALE	magnitude estimation				time (seconds)	line scale
STANDARDIZATION	fixed modulus		modulus equalization	external calibration	none	none
SAMPLE PRESENTATION	2 cm balls				1 ml measure	levelled spoon
NUMBER OF SAMPLES	10		10	12[1]	12[2]	12[2]
SAMPLES PER SITTING	5 + ref x 2 = 12			6	12	12
TRIAL REPEATS	3	2	2	2	2	2
PANELISTS	9	8	8	8	7	6

[1] duplicates were included in each sitting
[2] fresh canola products were added

that time. Samples tested at 4°C were evaluated immediately upon removal from the refrigerator. Spreadability samples and samples for mouthfeel properties were placed on ice packs for testing at 4°C. The samples were assigned three digit codes and presentation order was randomized for each panelist. Evaluations were carried out in individual sensory analysis booths under red lights to mask colour differences.

The assessment of mechanical properties were carried out on a total of ten products, the fresh canola products arrived later (Figure 13); duplicates of two products were included in each spreadability setting to check panel performance. Twelve products including the fresh samples of canola I were available for the assessments of mouthfeel parameters.

The firmness and work to soften tests were included on one ballot with six samples, including the references, provided for each parameter. Two sittings, run on consecutive days, comprised one evaluation, two evaluations at each temperature were performed. Room temperature testing was done first, refrigerator temperature testing was done the following week. Spreadability was judged on six samples at a sitting, with duplicates of the corn brick and sunflower tub products included in each set. One evaluation was performed per day with a brief break between sittings; testing for both temperatures was completed in four consecutive days. The samples for one evaluation of each mouthfeel parameter were presented at one sitting, panelists were encouraged to take a brief break during the sitting. Two evaluations at each temperatures were completed on four consecutive days.

The all female panels were volunteers from the students, staff and associates of the Department of Foods and Nutrition and had varying amounts of experience in sensory evaluation.

1. Mechanical Properties.

1.1 Definition of Tests and Sensory Task

1.1.1 Firmness was defined as the force required to obtain a given deformation (Figure 15). Panelists assessed the force required to compress the samples with the handle of a plastic spoon. The corn brick margarine was provided as the reference, and using magnitude estimation, all samples were assigned firmness scores relative to the reference. Free modulus was used; that is, the panelists were allowed to assign any score they felt appropriate to the reference. The reference was presented at the same temperature as the samples. Higher scores denoted firmer products.

1.1.2 Work to soften was defined as the resistance of a product to structural breakdown (Figure 15). Panelists first stirred the end point reference of vaseline (60%)-cornstarch (40%) to determine its consistency. Cornstarch was added to reduce the stickiness. After assigning a consistency score to the reference (free modulus was allowed) each of the tablespread samples was worked with a spoon handle until it reached the consistency of the reference. Samples were assigned magnitude estimation scores which reflected the amount of effort required to work the samples to the fixed end point. Higher scores reflected greater structural integrity.

+--+

Iextural Assessment of Tablespreads

1. Firmness: the force required to obtain a given deformation.

Compress the samples with the spoon hande. Score each sample on resistance to compression, relative to the first sample provided.

Sample	Score
--R---	-----

2. Work to soften: the resistance of a product to structural breakdown.

Feel the consistency of the reference sample with the spoon handle. Assign the reference a "work to softening" score. Work each of the samples with the spoon handle until they equal the softness of the reference. Assign scores relative to the amount of effort required to effect the desired consistency change.

Sample	Score
--R---	-----

3. Spreadability: the ease with which the sample can be applied in a thin even layer to bread.

Spread half the sample on the bread with the knife provided. Assign a spreadability score to each sample relative to the first sample. The more easily spread products receive a higher score. The remaining half sample can be used to confirm your initial impression.

Sample	Score
------	-----

Using the numerical scale that you used above assign scores which correspond to the following conditions.

Descriptor	Score
Too hard (will not spread)	-----
Too hard, just barely spreadable	-----
Hard, but satisfactorily spreadable	-----
Satisfactorily plastic and spreadable	-----
Soft but spreadable	-----
Very soft, oily, soaks into bread	-----
Very soft, almost pourable	-----

+--+

Figure 15: Abreviations of the Ballots Used for the Sensory Evaluation of the Mechanical Properties of Tablespread Texture

Scores for samples already softer than the end point were no longer work to soften but softness assessments; therefore scores for soft products were not reliable.

1.1.3 Spreadabilty was defined as the ease with which the sample could be applied in a thin even layer to bread (Figure 15). Panelists spread one-half the sample on plain white bread with a silver butter knife. The second half of the sample was used by the panelists to confirm their initial impressions if necessary. The first sample, randomly selected, served as a reference and all products were scored relative to it using magnitude estimation. The more easily spread samples received higher spreadabilty scores.

Panelists were then requested to assign the magnitude estimation scores to a seven point category scale to permit external calibration, a standarization technique suggested by Moskowitz (1977). The descriptors on the catagory scale were adapted from Haighton (1959) (Table 4) and ranged from too hard (will not spread), to satisfactorily plastic and spreadable, to very soft almost pourable.

1.2 Panel Training

Three training sessions were required to familiarize the panel members with the task required, with the technique of magnitude estimation and to refine the ballots. Training in magnitude estimation involved two exercises, one assessing the sizes of squares of paper and the other assessing the heaviness of small weights placed in coded paper cups. The latter test involved placing the weights on a balance scale and assessing the finger pressure required to make the scale balance. Two sessions of training with the actual samples and ballots were done; panelists scored the products, the results were recorded on a black board and discussed as a group.

1.3 Score Standardization

Firmness values for each sitting were adjusted to fix the modulus (reference value) at 10. The work to soften values were standardized using modulus equalization (Moskowitz, 1977); the overall geometric mean for each temperature and the geometric mean for each panelist/sitting were first calculated, the scores for each panelist/sitting were then adjusted by multiplying each score by the ratio of the two means. The geometric mean for each panelist's standardized values was then equal to the overall geometric mean of that testing temperature.

Spreadability values were standardized using external calibration; the pivot point for each sitting was the value assigned to category 4, suitably plastic and spreadable, or the ideal. Each magnitude estimate and category value was divided by the pivot point such that ideally spreadable was fixed to equal 1. The two internal references were included as independent samples in the analysis, providing the spread treatment with 11 degrees of freedom.

2. Mouthfeel Properties.

2.1 Definition of Tests and Sensory Task

2.1.1 Rate of mouthmelt was defined as the time required for a product to totally melt in the mouth (Figure 16). Panelists were instructed to take the entire sample into their mouths; the sample was then moved from side to side across the palate until melt was achieved. Panelists were reminded to keep a constant tongue pressure from sample

+--+

Textural Assessment of Tablespreads

1. Rate of Mouthmelt: the time required for a product to totally melt in the mouth.

Take the whole sample into your mouth. Move the sample from side to side across the palate with your tongue. Be sure to apply the same pressure to each sample. With the stop watch observe the time required to achieve melt. Record this time in the space provided.

Sample	Time to Melt (Seconds)
-----	------------

2. Graininess: the presence of discrete particles in a product.

There will be two judgements: the extent of graininess and the size of the particles, if present. Lick the sample into your mouth. On the first line for each sample, indicate with a vertical mark your assessment of the quantity of particles present. For those samples with particles please indicate the size of the particles by marking the second line.

Sample

----

no particles many particles

-------|---|------

chalky grainy

+--+

Figure 16: Abreviations of the Ballots used for the Sensory Evaluation of the Mouthfeel Properties of Tablespread Texture

to sample. Using stop watches the panelists recorded the time to melt in seconds.

2.1.2 Graininess was defined as the presence of discrete particles in a product (Figure 16). Panelists were requested to make two judgements on each sample: the extent of graininess and the size of the particles if present. Panelists ran their tongues over the surface of the sample transferring part of it into their mouths. While pushing the sample against the palate with the tongue the general number of particles present in the sample was noted on the six inch line scales provided. The end points on the scale were no particles and many particles. If particles were detected, panelists then marked on a second line scale the approximate size of the particles from chalky to grainy.

2.1.3 Mouthcoat and mouthcooling had been considered qualities that would be important in evaluating the mouthfeel properties of tablespreads. Attempts to rank products consistently in training sessions were unsuccessful and work on these parameters was not pursued.

2.2 Panel Training

Three training sessions were required for the rate of mouthmelt task to familiarize the panelists with the use of the stop watch and to practise uniform handling of the samples in the mouth.

Panelists required four training sessions to become comfortable with assessment of the graininess parameter. It was decided that both the number of particles present and the size of these particles could be assessed on a single sample. Training included ranking a starch slurry, pears and cream of wheat to familiarize the panelists with the particle size continuum of chalky, gritty and grainy respectively (Brandt, *et al.*, 1963).

Texturometer Testing

1. Testing Procedure

The General Foods texurometer was used as the testing instrument with the 5 cm brass plunger. The clearance was set at 4 mm, chart speed at 1500 mm/min. with low chewing speed, the voltage was adjusted according to the samples being tested. A plate with a small raised spike in the centre of raised concentric circles was made by Central Instrument Service, University of Manitoba, to prevent samples from slipping. Hardness was determined using the height of the first peak divided by volts used. Work to soften was estimated by comparing the difference in height between peak one and peak two, the reduction in hardness with work. Values thus obtained from the texturometer testing will be referred to as Texturometer Units, TUf and TUr respectively.

2. Sample Preparation

Sample balls were prepared as indicated for sensory testing of mechanical properties. Height for all brick and refrigerated tub samples was adjusted by placing the sample firmly on the spike of the sample plate and slicing along a wooden guide to height of 1.2 mm. The soft margarines could not be sliced in this way so were flattened using a spatula and the same guide. Three samples of each product were tested at each temperature (4°C and 21°C).

Statistical Analysis

Analysis of the textural data involved first testing for homogeneity of variance of the spread factor levels using Leven's test on a completely random model (Brown and Forsythe, 1974). Results from Leven's test indicated that $\log_{10}$ transformations decreased variance heterogeneity. Parametric analysis of variance (ANOVA) procedures were subsequently applied to the log transformed values of all textural data except graininess. The latter test generated zero values, therefore log transformations were contraindicated. The presence of graininess was tested for independence against panelist, temperature and market form using χ^2. The scores from one panelist were omitted from further analysis to ensure independence from this effect. The frequency with which particles were observed in each product and the mean and standard error of the mean (S.E.M.) were reported for the amount of particles and the size of the particles if present.

Analyses of variance for the sensory assessments of firmness were performed using a two factor fixed effects model: spread and panelist. Temperature could not be included since the reference was presented at the same temperature as the samples. Analyses of variance for the sensory assessments of work to soften, spreadability and rate of mouthmelt were performed on a three factor fixed effects model: spread, temperature and panelist. Analysis of variance for the texturometer tests used a two factor model: spread and temperature. The spread factor in all the analyses encompassed oil source, market form, manufacturer and storage if applicable. Post hoc comparisons of spread and oil source were performed by Scheffe's method at $\alpha=0.01$. Market form and storage, each at two levels were compared using a 2-tailed t test for which the test statistic was calculated from the mean square error of the ANOVA.

RESULTS

Fatty Acid Composition

The fatty acid compositions of the margarines (Table 6) were representative of the oil base from which they were made. The canola II brick margarine had a higher percentage of C16:0 than the approximately 5% expected suggesting that palm oil may have been added. The canola products contained the highest levels of C18:1, 65-70%, and the lowest levels of C18:2, 9-12%, with 1-2% C22:1. The highest levels of C18:2 were in the sunflower and corn products which contained from 31-45%, depending on market form. All products contained less than 1.5% C18:3 except for the soy tub product which had more than 4%.

The levels of total trans and cis-cis C18:2 influence both textural and nutritional qualities. When measuring the amount of geometric isomerization in the products, a discrepancy in the results from the two GLC columns was observed. The values of total C18:1 obtained from the SP column were consistently lower than the addition of cis C18:1 and trans C18:1 from the OV column. The C18:2 fraction displayed the opposite effect, that is, the total C18:2 from the OV column was consistently less than the C18:2 as measured on the SP column. This apparent shift of some of the C18:2 fraction into the C18:1 fraction may have accounted, in part, for the differences seen between the two methods of calculating total trans. The fatty acid profiles from the OV column contained a shoulder on the cis C18:1 peak, this was most noticable in

TABLE 6

Fatty Acid Composition of Selected Tablespreads Manufactured from Differing Vegetable Oil Bases

FATTY ACID[2] (g/100g methyl esters)	BRICK					TUB			
	Canola I[3]	Canola II	Corn	Soy	Sunflower	Canola[3]	Corn	Soy	Sunflower
X	+	+	-	+	-	+	+	0.1	-
C14	tr	0.3	tr	0.5	tr	tr	+	0.1	tr
X	+	tr	-	-	+	+	+	+	-
C16:0	5.7	8.3	11.0	10.5	6.5	4.1	11.1	10.7	6.6
C16:1	0.4	0.5	tr	tr	tr	0.4	tr	0.1	+
X	tr	0.2	-	tr	-	tr	+	tr	-
C18:0	6.9	8.1	5.7	8.8	11.3	5.3	6.3	7.4	9.2
Total C18:1	64.6	67.4	49.9	61.1	47.5	69.6	36.7	40.7	36.5
trans C18:1	34.6	29.4	26.5	28.1	22.1	21.9	11.3	13.7	15.2
cis C18:1	34.6	40.8	25.9	35.6	26.6	50.9	26.3	27.9	22.2
Total C18:2	13.7	8.6	31.8	16.0	31.7	11.2	44.0	34.9	45.2
cis-trans,trans-cis C18:2	4.5	1.8	-	1.6	tr	4.5	tr	1.1	-
cis-cis C18:2	6.2	3.8	29.6	11.6	28.3	4.5	42.4	33.0	42.3
C18:3	0.4	1.4	0.6	1.3	0.7	0.4	0.9	4.5	0.7
C20:0	1.2	tr	0.5	0.8	0.5	1.8	0.5	0.6	0.5
C20:1	3.4	2.4	0.4	0.6	0.7	4.1	0.4	0.4	0.5
C22:0	0.4	0.4	tr	0.4	0.8	0.4	0.1	0.3	0.8
C22:1	2.0	1.5	-	-	0.2	1.8	-	+	-
C24:0	-	-	-	+	-	-	-	+	-
Total *Trans*: minimum	39.1	31.1	26.5	29.7	22.2	26.5	11.3	14.8	15.2
maximum	42.1	34.1	28.6	32.5	25.5	28.6	12.8	15.7	18.1
I.R.[4] (%wt fat)	45.7	38.5	30.4	33.6	24.4	30.1	14.2	16.6	16.5

- not detected   + values < 0.05%   tr values > 0.05% but < 0.10%

x measurable unidentified peaks, noted in terms of relative time on the SP column.

[1]means of duplicate runs.

[2]values for geometric isomers determined on OV column.

[3]unidentified peak between C18:2 and C18:3 on the SP column approx. 1.0% in brick and 0.5% in tub.

[4]infrared--single determination.

the canola products (Figure 17). The second method of calculating total *trans* from the GLC data maximized the amount of *trans* fatty acids by assuming the shoulder to be *trans-trans* C18:2.

The IR values of total *trans* were consistently higher than the maximum calculated GLC values except for the sunflower products. The higher IR values may indicate the presence of *trans-trans* C18:2. Nevertheless the major proportion of the *trans* isomers were in the C18:1 fraction.

The corn and sunflower products contained the highest levels of apparent *cis-cis* C18:2 and the canola products the lowest. Both market forms of the corn and sunflower margarines and the soy tub margarine contained more than 25% apparent *cis-cis* C18:2, the minimum required level for a label statement claim of polyunsaturates content. The canola products contained the highest level of *trans* fatty acids. Within dominant oil species the brick margarines contained more *trans* fatty acids than the tub forms.

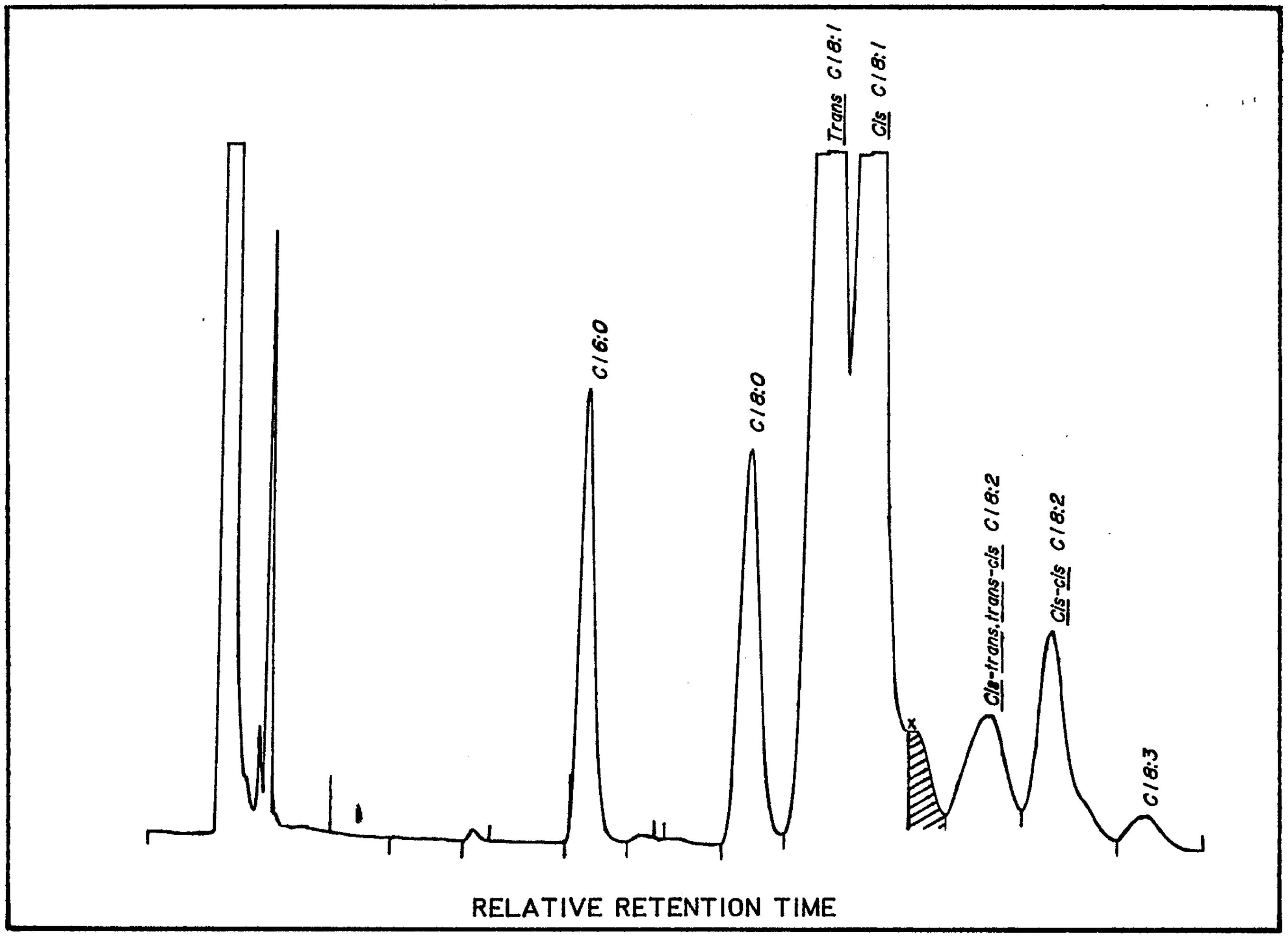

Figure 17: Fatty Acid Profile of Canola I Brick Margarine From GLC, OV-275 Column

x indicates the shoulder on the cis C18:1 peak believed to be be trans-trans C18:2

Physical Properties

Solid Fat Index (SFI)

The solid fat indices (Table 7) showed the gradual reduction in solids that was expected as the temperature increased. Comparison of oil sources pointed out the uniqueness of butter; it had the highest SFI at 10°C, a value comparable to the margarines at 21°C and the highest residual solids at 33°C. No major trends were noted among the margarines on the basis of oil source.

A comparison between the market forms of margarine showed that the bricks had a higher SFI at 10°C than the tubs. The SFI of the latter at 10°C was comparable to that of the bricks at 21°C. The low solids content of the tubs at 10°C is responsible for their spreadability at refrigerator temperatures. The bricks displayed a marked drop in solids between 10°C and 21°C, an average of 9 units, but the tubs showed much less change in solids, an average drop of 6 units, in that range. By 33°C the solids content for both groups was the same.

The sunflower spreads were anomolies in both the market forms. The brick sunflower had a slightly lower SFI at 10°C, 18.5-23%, as compared to 22.5-28% for the other bricks. The sunflower brick was not notably different in solids content than the other bricks at 21°C and 33°C. In contrast to the low solids of the sunflower brick the sunflower tub had higher solids content at both 10°C and 21°C than the other tub products. The slightly higher solids content of the sunflower tub would lend it more structural integrity than that expected in a tub product.

TABLE 7

Solid Fat Indices of Tablespreads[1]

PRODUCT	10°C	21.1°C	33.3°C
Brick:			
Butter[2]	34.3	11.8	6.1
Canola I[2]	25.5	13.6	2.5
Canola II	24-26	13.5-15	2-3.5
Corn	22.5-24	14-16	2-3
Soy	16-28	14-16	1.5-3
Sunflower	18.5-23	12-14	2.5-4.5
Tub:			
Canola[2]	11.7	4.9	0
Corn, Soy	10-12	4-6	2-3
Sunflower	13.5	8	1.5-3

[1] SFI values provided by the manufacturers
[2] SFI's performed by Foods and Nutrition Lab

Differential Scanning Calorimetry (DSC)

Analysis by DSC was rudimentary; the lack of a coefficient of variation on the method used does not permit definitive statements regarding sample differences. The findings can be considered as only exploratory.

The melting thermograms of the unmelted samples which were cooled and melted from the solid state, were all similar in shape (Figure 18). Products displayed exothermic peaks between -50°C and -40°C. Although these peaks were smaller for canola I brick (later run), corn brick and canola tub, no pattern emerged by either oil source or market form. Two salt-affected areas of melt were observed: the salt-water eutectic melt at -22°C and the solute depressed melt of water at -8°C. The sunflower products displayed less pronounced eutectic melt. The salt effectively masked fat melt peaks which might have been present below 0°C.

Melt was continuous for all products as temperature increased above 0°C and complete melt had occured by 48°C; melt end points were defined by the levelling off of the thermogram. Margarines displayed only one area of sharp melt; this occured in the range between 30°C and 40°C. Butter had a distinctive melt pattern with three relatively sharp melt peaks: 7°C, 17°C and 35°C.

Two runs of the canola I product were obtained 11 months apart, the thermogram of the product which had been stored for 11 months had shorter peaks at -44°C and a dual peak in the 30°C melt range. This change in melt pattern might reflect crystal changes.

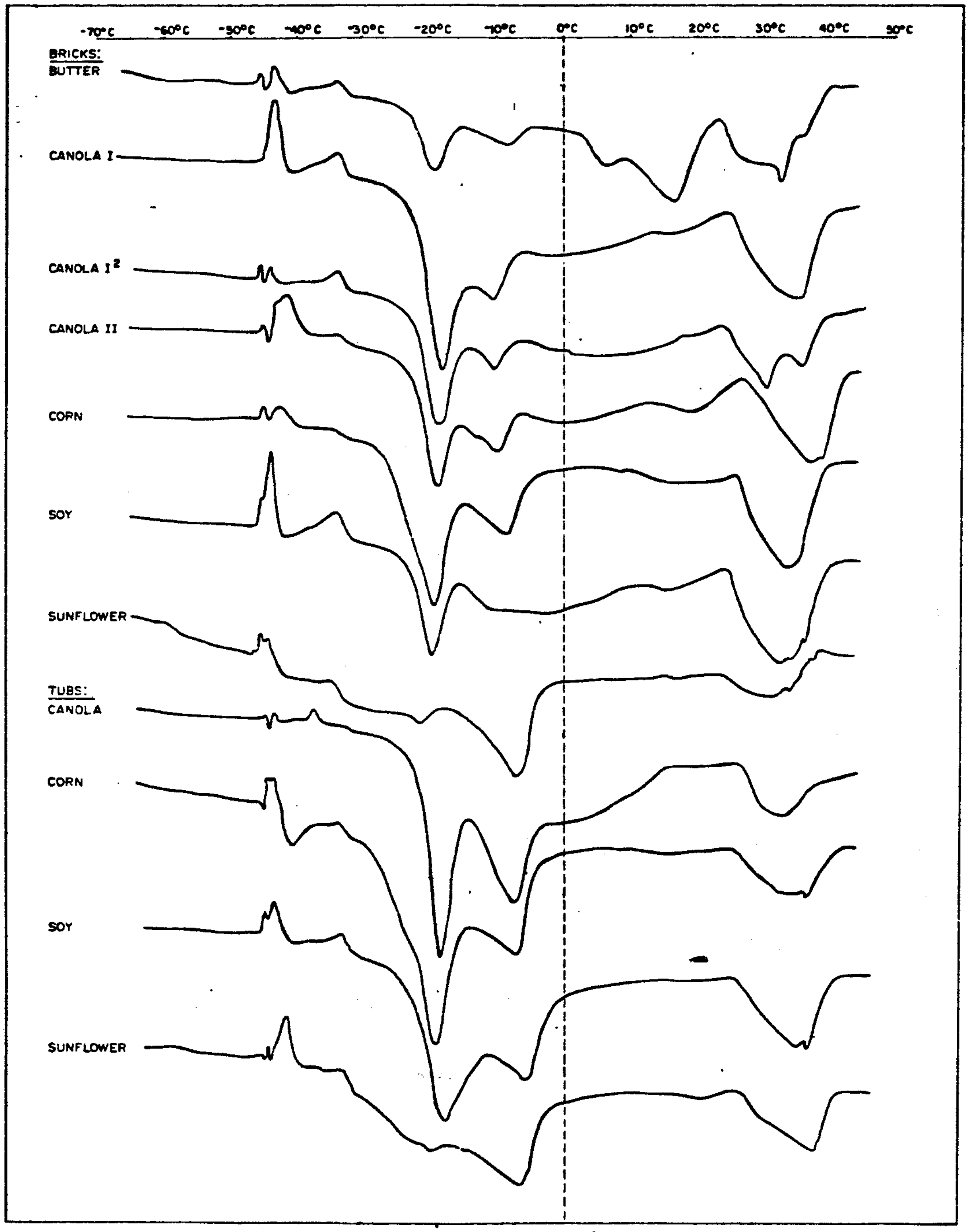

Figure 18: Melting Thermograms Obtained on Unmelted Tablespread Samples

[1]Samples were loaded directly from a freezer, cooled to -70°C and heated to 50°C at 5°C/min. to obtain the thermograms.
[2]Sample was rerun after 11 months storage.

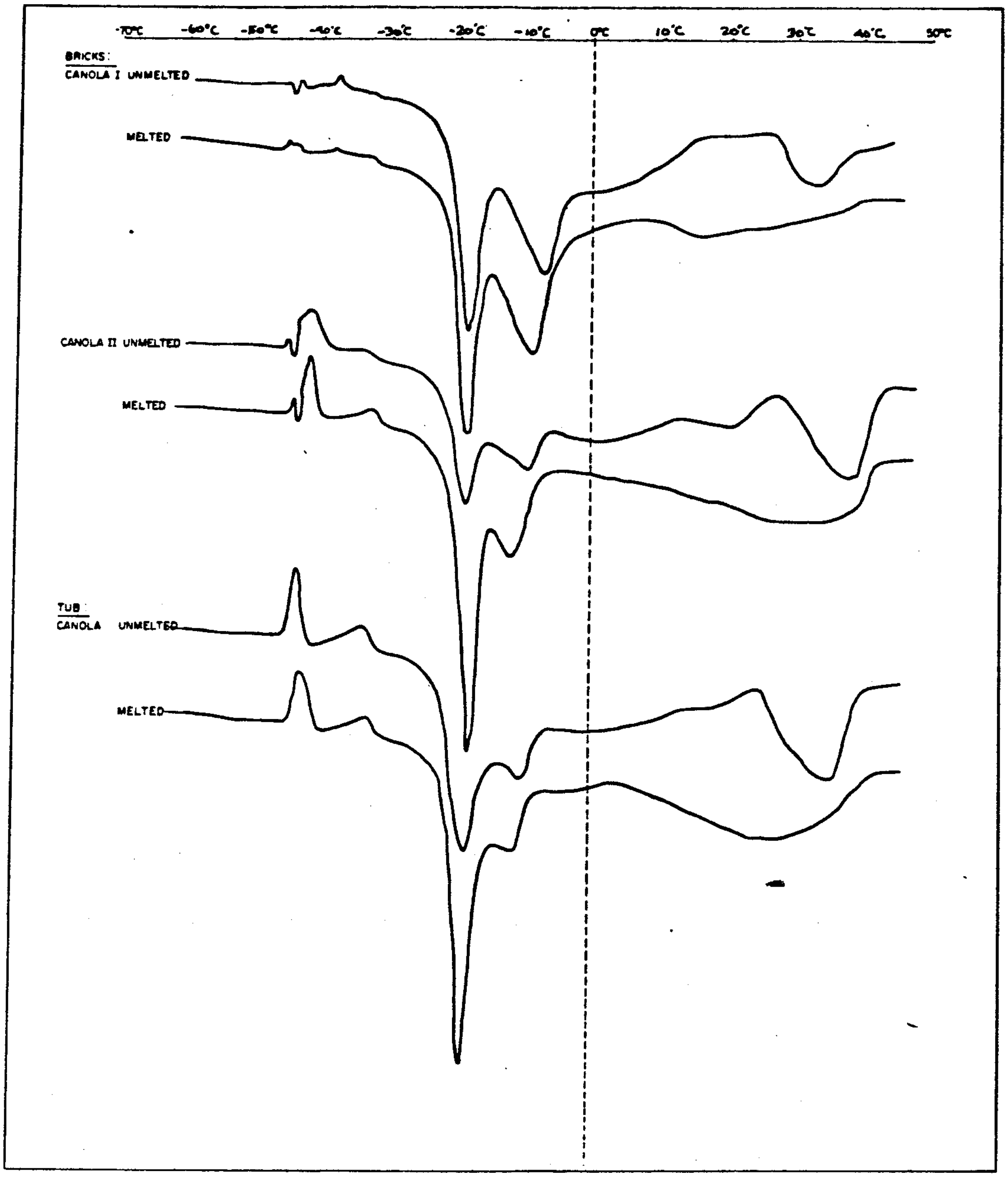

Figure 19: Melting Thermograms Obtained From Unmelted and Melted Tablespread Samples

[1]Samples were loaded directly from a freezer, cooled to -70°C, and heated to 50°C (Thermogram of Unmelted Sample), held for 10 min. to erase thermal history, cooled to -70°C and heated at 5°C/min. to 50°C (Thermogram of the Melted Sample).

The thermograms obtained from the melted samples (Figure 19) displayed more pronounced salt-water eutectic melt due, probably, to the break in the emulsion caused by melt; the melt peaks occuring between 30°C and 40°C were flattened compared to the same products run from the unmelted state. Since all products displayed the same differences between the unmelted and melted thermograms, only three representative products are shown in Figure 19.

The total energy uptake of the tablespreads (Table 8) ranged from 40.55 mcal/mg for canola I brick to 29.17 mcal/mg for sunflower tub. The overall mean was 35.09 mcal/mg.

The thermograms were divided into four stages of melt in the expectation that comparisons among the products within each stage of melt would indicate textural differences. That is, the extent of melt below 4°C would reflect the amount of solids remaining at refrigerator temperatures, the melt occuring between 4°C and 21°C would represent stability at room temperatures and the residual solids and melt end point would reflect the mouthmelt sensation. A series of analyses of variance within each melt range was obtained; there was a significant oil source effect in the 4-21°C melt range and a significant difference between market forms in the 4-21°C and 21-33°C ranges (Table 9).

The multiple comparisons among the oil source effects within each melt range showed that canola had a significantly higher energy uptake in the 4°C-21° range than the other oil sources (Table 10). No other significant differences among oil sources were present but some interactions were suggested. Soy displayed a consistent rise from the lowest energy uptake in the <4°C melt range to the highest residual

TABLE 8

Energy Uptake (mcal/mg) of Tablespreads During Specified Stages of Melt

PRODUCT	<4°C	4°C-21°C	21°C-33°C	>33°C	TOTAL
Brick:					
Butter	15.58	13.52	7.35	2.49	38.94
Canola I	24.08	6.86	5.20	4.40	40.55
Canola I[1]	19.00	7.94	5.53	2.93	35.40
Canola II	19.28	7.31	3.32	5.60	35.51
Corn	21.02	4.05	5.62	4.11	34.81
Soy	16.58	5.78	5.54	4.32	32.22
Sunflower	23.25	3.29	3.47	0.79	30.79
Tub:					
Canola	26.84	5.16	2.61	2.38	36.99
Corn	29.60	2.63	2.58	2.63	37.44
Soy	24.69	3.04	2.92	3.54	34.19
Sunflower	21.81	2.12	2.12	3.12	29.17

[1] Sample was rerun after 11 months storage

TABLE 9

Mean Squares (MS) from the Analysis of Variance for Tablespread Energy Uptake in Four Melt Ranges[1]

SOURCE OF VARIANCE	D.F.	<4°C MS	4°C-21°C MS	21°C-33°C MS	>33°C MS
Oil source	3	10.2	4.2*	1.0	1.4
Market form	1	38.0	6.2*	11.1*	0.5
Error	3	10.6	0.2	0.3	1.9

[1] obtained from DSC (Table 8)

*significant at α=0.01

TABLE 10

Energy Uptake of Tablespreads During Melt Compared by Oil Source and Market Form[1]

MELT RANGE	OIL SOURCE				MARKET FORM	
<4°C	Soy	Sunflower	Corn	Canola	Brick	Tub
	20.64	22.53	25.02	25.46	21.23	25.59
4°C-21°C	Sunflower	Corn	Soy	Canola	Tub	Brick
	2.71a	3.34ab	4.41b	6.01c	3.24a	5.00b
21°C-33°C	Sunflower	Canola	Corn	Soy	Tub	Brick
	2.71	3.91	4.10	4.23	2.56a	4.92b
>33°C	Sunflower	Corn	Canola	Soy	Tub	Brick
	1.96	3.37	3.39	3.93	2.92	3.42
Total	Sunflower	Soy	Corn	Canola	Tub	Brick
	21.91	33.21	35.83	38.77	34.56	34.31

[1] means, within an effect, with no letters were not significantly different
abc means, within an effect and row, followed by the same letter were not significantly different at $\alpha=0.05$

melt. Sunflower remained near or at the lowest in energy uptake across all melt ranges with the lowest energy uptake overall. Corn remained in the midrange of energy uptake across all ranges and canola showed no trend but did have the highest total energy uptake.

There was a significant market form effect at both the 4°C-21°C and 21°C-33°C melt ranges (Table 9), brick products having significantly more energy uptake than tubs (Table 10). The tubs tended to have a higher energy uptake in the <4°C melt range. The interaction of market form with melt range was as expected; the greater degree of melt of the tubs at the low temperature range confers the desirable spreadability of these products at refrigerator temperatures. At temperatures >4°C the bricks displayed catch-up melt such that all products were totally melted by 48°C. Both market forms required essentially the same total energy to melt (Table 10).

The areas of transition were more easily noted when the energy uptake within the specified temperature ranges was calculated as a percent of total energy used (Figure 20). In the melt area below 4°C, butter had a lower percentage energy use than the margarines. Within the margarines the brick forms, except sunflower, had less energy uptake, 51-60%, than the tub forms, 72-79%. Lower amounts of energy used in the range below 4°C suggested that the brick products had undergone less melt than the tubs, accounting for the structural integrity of the brick products, including butter, at 4°C. The sunflower brick product displayed a relative melt pattern very similar to the tub forms in this analysis.

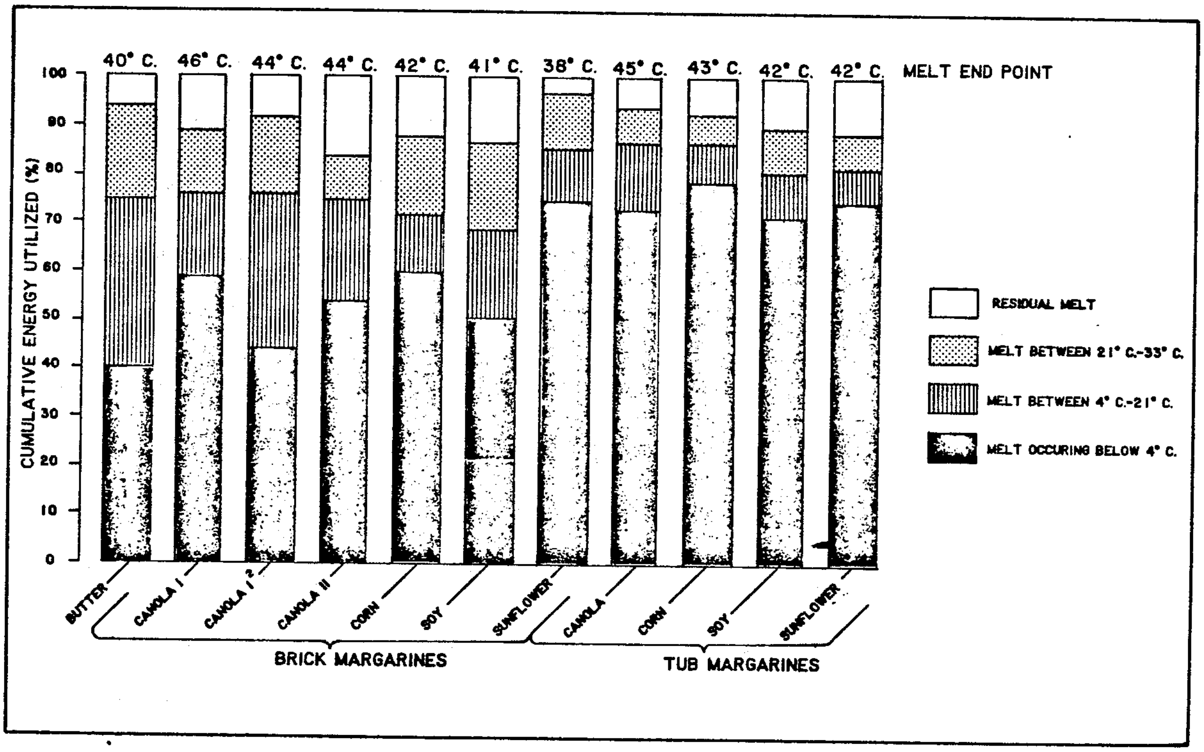

Figure 20: Percent Energy Used by Tablespreads for Transitions Occuring before 4°C, 21°C and 33°C

[1]Calculated from DSC melt thermograms
[2]Sample was rerun after 11 months storage

Butter had 35% of its energy uptake in the range between 4-21°C , the margarines ranged between 7-22%. In the area between 21° and 33°C the brick margarines caught up to the tubs in amount of melt such that no real difference in residual melt was noted. The melt end points were highest for the canola products (44-46°C) and lowest for the sunflower brick (38°C) (Figure 20). The other products ranked corn, soy, sunflower by decreasing melt end points.

Textural Assessments

Test for Homogeneity of Variance

Results of Leven's test suggested that confidence could be placed in the results of the analysis of variance of the work to soften and rate of mouthmelt tests (Table 11). Caution however is indicated when considering the results of the other texture tests. Violations of the homogeneity assumption would inflate the F statistic causing the differences between the treatment means to appear greater then they actually were. Part of the heterogeneity of variance of the sensory firmness assessments and spreadability categories was due to the fixed modulus of the former and the pivot point used to adjust the scores of the latter; these treatments by definition had variances equal to zero (page 46).

To compensate for the possibility of the inflated F statistic in the analysis of variance of each set of data, a significance level of 0.001 was used. Furthermore Scheffe's multiple comparison procedure was chosen to compare treatment means because it is more robust to violations of homogeneity of variance than the alternative post hoc procedures. Post hoc comparisons were performed at α=0.01.

TABLE 11

Results of Leven"s Test for Homogeneity of Variance in the Textural Data

DATA	F TEST STATISTIC	TAIL PROBABILITY[1]
Sensory:		
Firmness-4°C	5.96	0.00%
Firmness-21°C	8.38	0.00%
Work to Soften	1.28	19.26%
Spreadability-Panel	7.51	0.00%
-Catagory	21.48	0.00%
Rate of Mouthmelt	1.36	12.99%
Texturometer:		
Firmness	2.39	0.54%
Reduction in Firmness	3.62	0.01%
Cohesiveness	2.36	0.60%

[1] homogenity of variance was accepted at p>5%

Mechanical Properties

1. Firmness.

There was a significant difference in the firmness among the spread treatments in the sensory firmness scores at both temperatures and in the texturometer measurements incorporating temperature (Table 12). The temperature effect could not be tested in the sensory analysis, however, it was found to be significant in the texturometer analysis. The mean firmness of 0.61 LTUf at 4°C was significantly greater than the mean firmness of 0.12 LTUf at 21°C. There was a significant panelist effect at 21°C, this was due to the differing widths of ranges used by the panelists which were not ameliorated by standardizing to a fixed modulus (Moskowitz, 1977). There were no significant differences between the replications; indicating consistency of sample prepartion and handling.

The significant spread X temperature interaction, in the texturometer data, was largely contributed by the change in firmness ordering within market forms of two products: butter and canola tub; each was the firmest of its respective market form at 4°C and the softest at 21αC (Figure 21). The sunflower brick displayed the next largest inversion of rank between temperatures, going from a medium firm brick at 21°C to the softest brick product at 4°C. The lack of significant interaction between spread and panelist suggested that the panelists were ordering the products the same way (Table 12).

TABLE 12

Firmness Assessments of Tablespreads - Analysis of Variance

	SENSORY PANEL				TEXTUROMETER	
	4°C		21°C			
Source of Variation	d.f.	MS	d.f.	MS	d.f.	MS
Spread	10	3.16*	10	3.24*	11	0.48*
Temperature	--	--	--	--	1	4.14*
Panelist	7	0.10*	8	0.14	--	--
Replications	1	0.03	2	0.02	2	0.00
S X T	--	--	--	--	11	0.06*
S X P	70	0.05	80	0.03	--	--
Error	87	0.03	196	0.02	46	0.002

*significant at α=0.001

-- not applicable to test

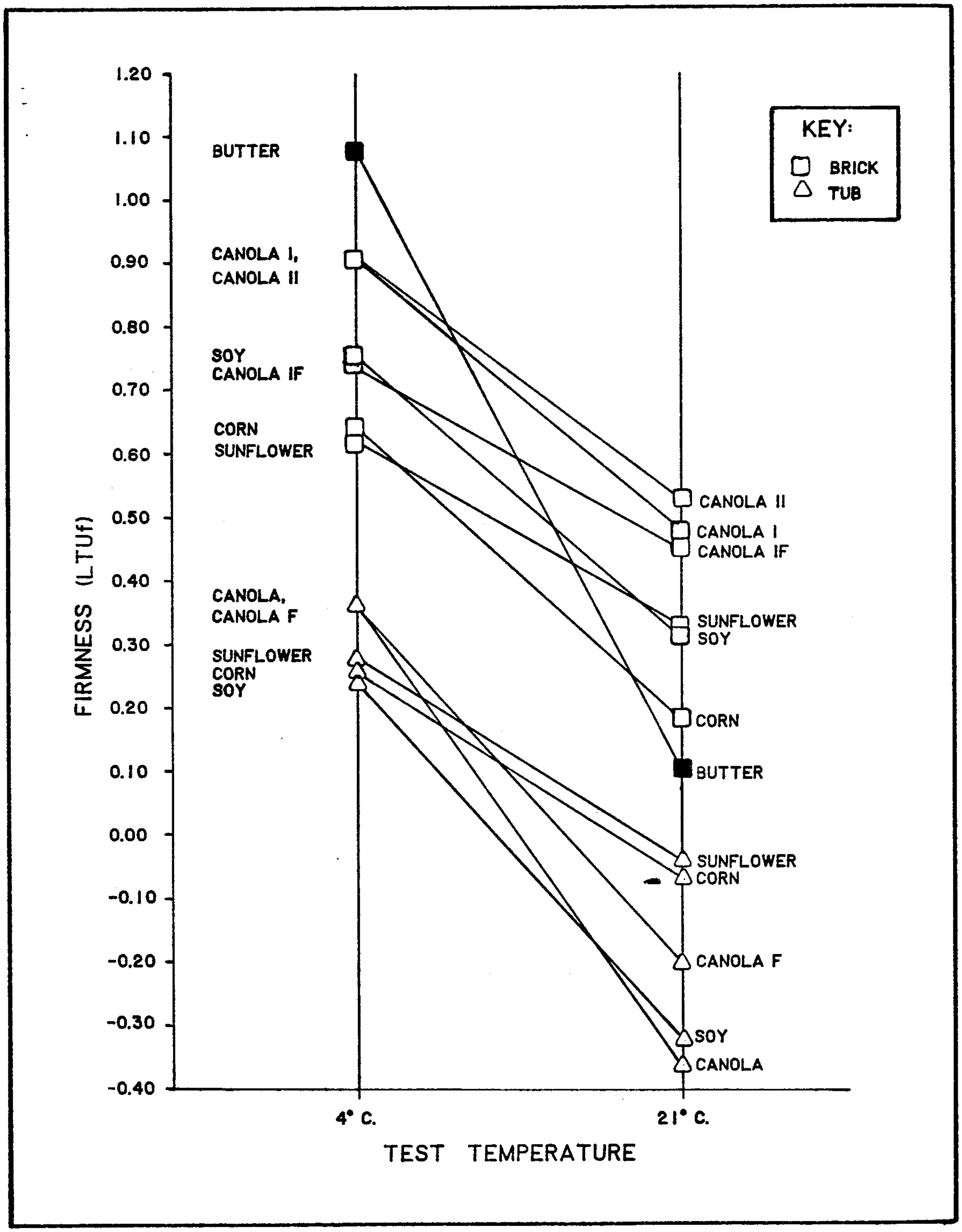

Figure 21: Firmness of Tablespreads -- Spread X Temperature Interaction

TABLE 13

Firmness Assessments -- Comparisons Among Tablespreads

PRODUCT	LOG SENSORY PANEL SCORES (LSf) 4°C[2]		21°C[3]		LOG TEXTUROMETER UNITS[1] (LTUf) 4°C		21°C	
	Mean	S.E.M.	Mean	S.E.M.	Mean	S.E.M.	Mean	S.E.M.
Brick:								
Reference	1.00 bc	0.000	1.00 c	0.000	--	--	--	--
Butter	1.77 a	0.074	1.06 c	0.028	1.08 a	0.021	0.10 hi	0.040
Canola I	1.66 a	0.075	1.36 a	0.037	0.91 ab	0.014	0.48 de	0.008
Canola I F	--	--	--	--	0.74 bc	0.012	0.45 def	0.015
Canola II	1.54 a	0.054	1.28 ab	0.038	0.91 ab	0.033	0.53 de	0.042
Corn	1.04 b	0.021	0.99 c	0.021	0.64 cd	0.009	0.18 ghi	0.000
Soy	1.19 b	0.041	1.12 bc	0.035	0.75 bc	0.018	0.32 efgh	0.007
Sunflower	1.12 b	0.042	1.42 a	0.036	0.62 cd	0.027	0.33 efgh	0.035
Tub:								
Canola	0.61 d	0.052	0.38 f	0.047	0.35 efg	0.017	-0.36 k	0.031
Canola F	--	--	--	--	0.36 efg	0.044	-0.20 jk	0.012
Corn	0.56 d	0.068	0.73 d	0.025	0.25 fgh	0.014	-0.07 ij	0.017
Soy	0.53 d	0.058	0.51 ef	0.037	0.25 fgh	0.025	-0.32 k	0.027
Sunflower	0.70 cd	0.038	0.65 de	0.031	0.28 fgh	0.013	-0.04 ij	0.039

[1]n=3,means followed by the same letter were not significantly different at α=0.01
[2]n=27,means followed by the same letter were not significantly different at α=0.01
[3]n=16,means followed by the same letter were not significantly different at α=0.01
-- not applicable to test
F, fresh

The panel firmness assessments of the corn brick and the identical reference sample were equal, suggesting panel accuracy (Table 13); however, as the product firmness departed from that of the reference product, the standard error increased proportionately to a maximum of 0.075 at 4°C and 0.047 at 21°C. Panelists scores sorted the products into six distinct firmness groups at 21°C and into four groups at 4°C, this trend was supported by the texturometer assessment and can be seen more easily in Figure 21; the tub products had a much greater range of firmness at 21°C than at 4°C. At 4°C the tubs were essentially all equal in firmness. The texturometer assessments did not sort the products as clearly as did the sensory assessments, that is, the texturometer evaluation showed more overlapping of groups. The means of the firmness assessments (Table 13) showed that both the texturometer and sensory assessments clearly sorted the brick from the tub market forms. The mean texturometer assessments, incorporating temperature, showed that the brick products at 21°C were similar in firmness to the tub products at 4°C.

Comparisons among oil sources showed that the butter and canola bricks were significantly firmer than the corn, soy and sunflower products at 4°C (Table 14); however at 21°C the canola brick was still one of the firmest products but butter was included in the softer group. Sunflower brick displayed the opposite effect; it was one of the softest products at 4°C but maintained structural integrity to become the firmnest product at 21°C. The results from the texturometer analysis, incorporating temperature, point out that in general, butter was firmer than the brick margarines. The corn brick was the softest product in the three analyses of oil source. The identical vegetable oil sources

TABLE 14

Firmness Comparisons by Oil Source, Market Form and Storage Effect

FACTOR	TEST		TREATMENT				
Oil Source	Sensory-4°C	Brick:	Butter	Canola	Soy	Sunflower	Corn
		Mean	1.76a	1.60a	0.19b	1.12b	1.04b
		n	16	32	16	16	16
		TUB:	Sunflower	Canola	Corn	Soy	
		Mean	0.70a	0.61a	0.56a	0.53a	
		n	16	16	16	16	
	Sensory-21°C	Brick:	Sunflower	Canola	Soy	Butter	Corn
		Mean	1.42a	1.32a	1.12b	1.05b	0.99b
		n	18	36	18	18	18
		Tub:	Corn	Sunflower	Canola	Soy	
		Mean	0.73a	0.65a	0.38b	0.05c	
		n	18	18	18	18	
	Texturometer	Brick:	Canola	Butter	Soy	Sunflower	Corn
		Mean	0.71a	0.59b	0.53bc	0.47cd	0.41d
		n	12	6	6	6	6
		TUB:	Sunflower	Corn	Canola	Soy	
		Mean	0.12a	0.09a	-0.002b	-0.03b	
		n	16	16	16	16	
Market Form	Sensory-4°C		Brick	Tub			
		Mean	1.25a	0.60b			
		n	80	64			
	Sensory-21°C	Mean	1.22a	0.57b			
		n	135	108			
	Texturometer	Mean	0.53a	0.05b			
		n	24	24			
Storage	Texturometer		Stored	Fresh			
		Mean	0.34a	0.34a			
		n	12	12			

abc means within a row, followed by the same letter are not significantly different at $\alpha=0.01$

in the tub products displayed slightly different behavior; there was no significant difference at 4°C; however, at 21°C the products ranked corn and sunflower the firmest, canola intermediate and soy the softest. Incorporating temperature, as in the texturometer data, maintained the differences in firmness ranking among the oil sources within the tub market form. As would be expected, the brick products were significantly firmer than the tub market form (Table 14); however there was no significant storage effect on the firmness of the canola products as measured the the texturometer, even though the products differed in age by 10 months (Figure 13).

Correlation coefficients of the sensory with texturometer assessments were 0.99 at 4°C and 0.95 at 21°C (Figure 22). The correlation at 21°C was likely reduced by the inversion of the sunflower brick product. The panelists scored it as one of the firmest products whereas the texturometer assessments placed it as a soft brick (Table 13). No explanation can be made for this anomaly. The slopes of the line describing the relationship of the sensory with texturometer assessments for each temperature, 1.50 and 1.12 at 4°C and 21°C respectively, were not significantly different at α=0.01; therefore, the equation for the best fit line generated at 4°C was used to estimate sensory firmness at 21°C (Figure 22). As the estimated values fall outside the regression relationship the predictive value decreases.

2. Work to Soften.

There were significant differences among the spreads for both the sensory and texturometer assessments of work to soften (Table 15).

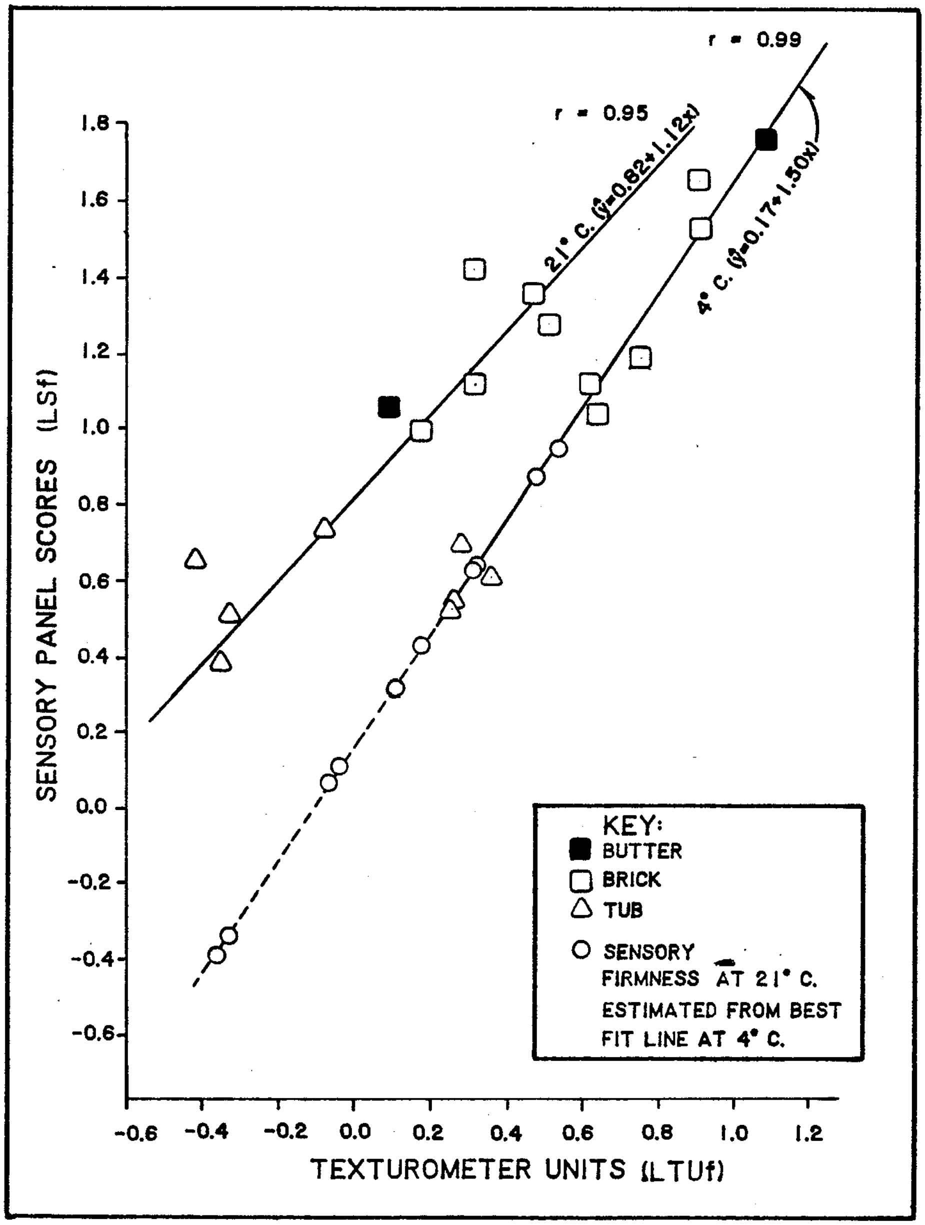

Figure 22: Relationship of Sensory with Texturometer Assessments of Tablespread Firmness

Exploration of the significant temperature effect (Table 16) showed that for both sets of data there was greater resistance to work softening at 4°C than at 21°C. There was no significant panelist or replication effect (Table 15).

The temperature X spread interaction (Figure 23) was mainly contributed by butter which showed little resistance to work softening at 21°C but was much more resistant at 4°C. Although the sensory panel and the texturometer ranked the products differently, the butter X temperature interaction was similar in both sets of data. Sunflower brick contributed to the sensory spread X temperature interaction by undergoing relatively little change in resistance between the two temperatures; sunflower tub established a similar trend in the texturometer assessment. The panelist X spread interaction, although significant, was small in magnitude compared to the other main effects and did not compromise further interpretation (Table 15).

Multiple comparisons were used to test the differences among all levels of the spread factor (Table 17). The sensory assessments sorted the products more clearly with less overlapping of groups than did the texturometer assessments. The brick products at 4°C had the greatest resistance to work softening, the tubs at 4°C were similar to the bricks at 21°C, and the tubs at 21°C were the easiest to work soften. The texturometer value reported for the soy tub product may not be reliable as the difference between the peak heights was a negative value, since negative numbers can not be logged the values for this product were estimated to be 0.01 cm, a value approximating zero.

TABLE 15

Work to Soften -- Analysis of Variance

	SENSORY		TEXTUROMETER	
	Work to Soften		Reduction in Hardness	
Source of Variation	d.f.	MS	d.f.	MS
Spread	9	3.17*	11	1.41*
Temperature	1	14.10*	1	9.37*
Panelist	7	0.00	--	--
Replication	1	0.00	2	0.06
S X T	9	0.26*	11	0.18*
S X P	63	0.08*	--	--
T X P	7	0.00	--	--
S X P X T	63	0.04	--	--
Error	159	0.03	46	0.02

*significant at α=0.001

TABLE 16

Effect of Temperature on Work to Soften Assessments of Tablespreads

TEST	4°C	21°C
Sensory:[1]		
Work to Soften	1.66a	1.24b
Texturometer:[2]		
Reduction in Hardness	-0.03a	-0.74b

[1] n=160
[2] n=36
abc means within a row, followed by the same letter are not significantly different at $\alpha=0.01$

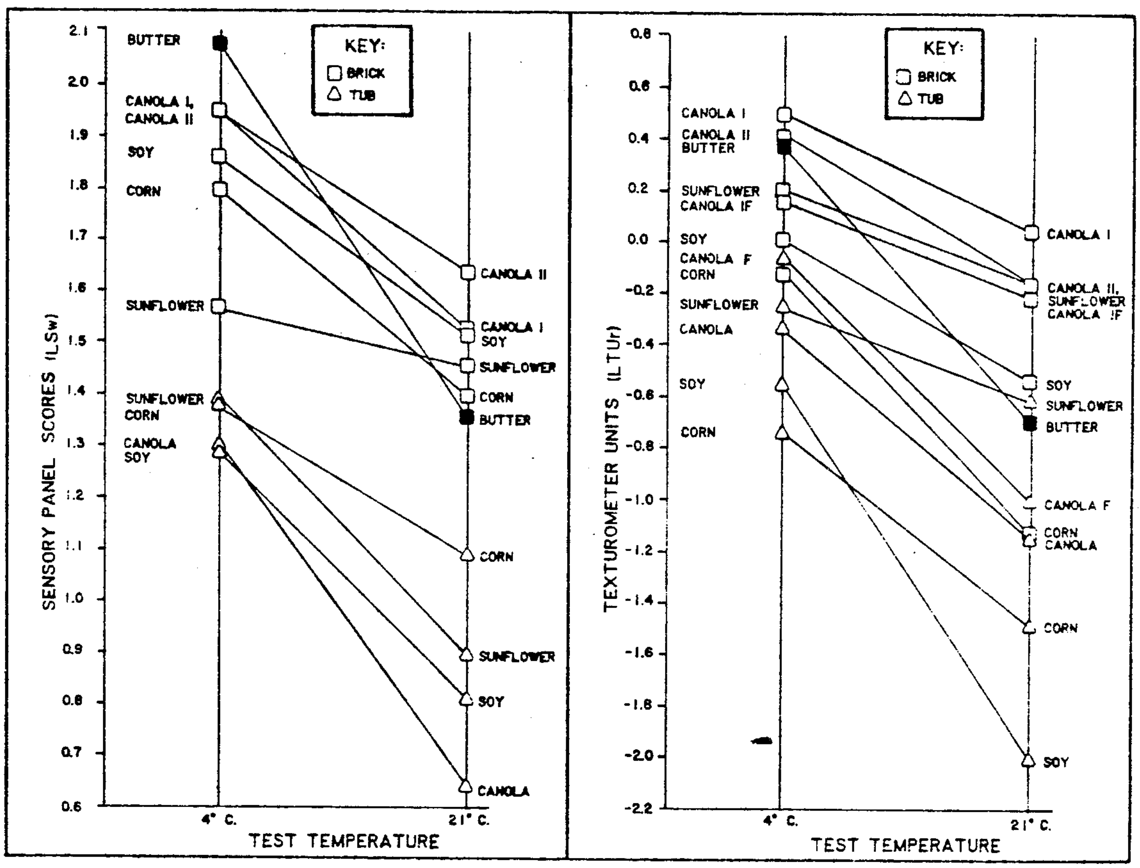

Figure 23: Work to Soften Assessments of Tablespreads -- Spread X Temperature Interaction

TABLE 17

Work to Soften Assessments -- Comparisons Among Tablespreads

	LOG SENSORY SCORES[1] (LSw)		LOG TEXTUROMETER UNITS[2] (LTUr)	
Product	Mean	S.E.M.	Mean	S.E.M.
4°C				
Brick:				
Butter	2.08 a	0.062	0.37 ab	0.133
Canola I	1.95 ab	0.062	0.51 a	0.095
Canola I F	--	--	0.16 abc	0.044
Canola II	1.95 ab	0.045	0.40 ab	0.036
Corn	1.80 abc	0.039	-0.12 abcdef	0.033
Soy	1.86 abc	0.054	0.01 abcd	0.040
Sunflower	1.57 bcd	0.034	0.20 abc	0.040
Tub:				
Canola	1.30 def	0.065	-0.33 cdef	0.028
Canola F	--	--	-0.06 abcde	0.020
Corn	1.38 de	0.042	-0.74 fg	0.042
Soy	1.29 def	0.048	-0.55 defg	0.072
Sunflower	1.39 de	0.037	-0.25 bcdef	0.024
21°C				
Brick:				
Butter	1.36 de	0.046	-0.69 efg	0.069
Canolo I	1.53 cd	0.046	0.05 abcd	0.034
Canola I F	--	--	-0.21 bcdef	0.031
Canola II	1.64 bcd	0.055	-0.16 bcdef	0.078
Corn	1.40 de	0.049	-1.14 gh	0.196
Soy	1.52 cd	0.053	-0.53 defg	0.090
Sunflower	1.46 cde	0.051	-0.16 bcdef	0.040
Tub:				
Canola	0.64 h	0.053	-1.14 gh	0.019
Canola F	--	--	-1.01 gh	0.078
Corn	1.09 efg	0.054	-1.48 hi	0.139
Soy	0.80 gh	0.066	-2.00 i	0.00
Sunflower	0.90 fgh	0.072	-0.61 defg	0.042

[1] n=16
[2] n=3
abc means within a column, followed by the same letter are not significantly different at α=0.01

Comparisons among oil sources within the brick market form show that the canola brick was the most resistant to work softening as measured by both the panel and the texturometer (Table 18). The panel scores did not sort the products as decisively as did the texturometer assessments; the former established two distinct groups whereas the latter established four groups. In general the sunflower, butter and soy were intermediate in resistance to work softening and the corn exhibited the least resistance of the brick products to softening. The relative ranking of the products between the two sets of data was different; however, the actual differences may have been minor. The problem of inversion of product ranks between the test instruments which occurred in the oil source comparisons, within the brick products, also occurred in the oil source comparisons within the tub products. The texturometer clearly measured the sunflower tub as the most resistant to work softening, canola as intermediate and corn and soy as the least resistant. The brick products were significantly more resistant to work softening than the tubs; there was no significant difference between the fresh and stored canola products.

The linear relationship between the sensory and texturometer assessment of work to soften was significant, with a correlation coefficient of 0.83, however when plotted (Figure 24) there were some obvious incongruities. The values for the tub spreads at 21°C showed the most extreme divergence from the best fit line. The distance of the points from the line suggested that the panelists and the instrument were assessing different parameters. As mentioned in the methods, the panelists had difficulty with the assessment of work to soften when the sam-

TABLE 18

Work to Soften Comparisons by Oil Source, Market Form and Storage Effect

FACTOR	TEST		TREATMENT				
Oil Source	Sensory	Brick:	Canola	Butter	Soy	Corn	Sunflower
		Mean	1.77a	1.72ab	1.69ab	1.60ab	1.51b
		n	32	16	16	16	16
		Tub:	Corn	Sunflower	Soy	Canola	
		Mean	1.23a	1.14ab	1.05ab	0.97b	
		n	16	16	16	16	
	Texturometer	Brick:	Canola	Sunflower	Butter	Soy	Corn
		Mean	0.20a	0.02ab	-0.16bc	-0.26c	-0.63d
		n	12	6	6	6	6
		Tub:	Sunflower	Canola	Corn	Soy	
		Mean	-0.43a	-0.73b	-1.11c	-1.28c	
		n	6	6	6	6	
Market Form	Sensory			Brick	Tub		
		Mean		1.64a	1.10b		
		n		128	128		
	Texturometer	Mean		-0.15a	-0.89b		
		n		24	24		
Storage	Texturometer			Stored	Fresh		
		Mean		-0.23a	-0.28a		
		n		12	12		

abc means within a row, followed by the same letter were not significantly different at α=0.01

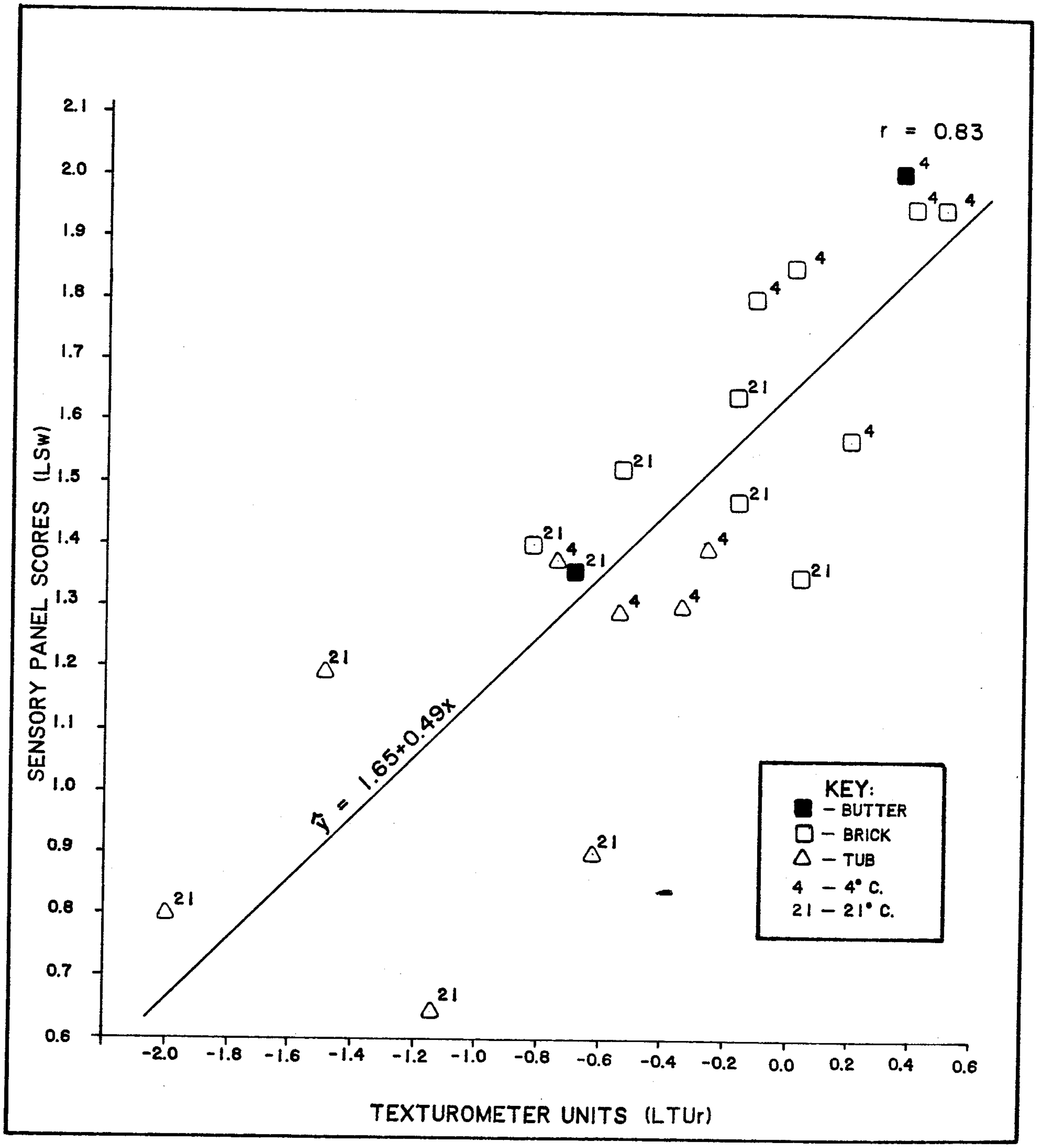

Figure 24: Relationship of Sensory with Texturometer Assessments of Tablespread Work to Soften

ples were already softer than the reference end point; values were then assigned on the basis of firmness. The work to soften parameter was expected not only to be a function of the initial firmness and the extent of primary bonding in the products, but also to encompass an additional parameter of plasticity; the latter would depend on the relative amounts of secondary bonding as discussed briefly on page 26. The correlation coefficient of sensory work to soften with firmness as measured by the texturometer was 0.97; the correlation coefficient of texturometer reduction in firmness with texturometer firmness was 0.90. The panelists may have been assigning firmness scores whereas the texturometer assessments may have been approximating the work to soften parameter as it was envisioned.

3. Spreadability.

The analysis of variance of the spreadability data showed that there were significant differences among the spreads, between the temperatures, and among the panelists; all the interactions were significant (Table 19). There was no significant difference between the replications.

The mean spreadability score of -0.47 at 4°C was significantly less than the mean spreadability score of 0.03 at 21°C. The significant panelist effect was apparently caused by the individual perceptions of spreadability, some panelists were scoring all the products as less spreadable while others scored all the products as relatively more spreadable.

TABLE 19

Spreadability of Tablespreads -- Analysis of Variance

Source of Variation	d.f.	MS
Spread	11	3.65*
Temperature	1	24.44*
Panelist	7	0.25*
Replication	1	0.15
S X T	11	1.18*
S X P	77	0.06*
T X P	7	0.41*
S X T X P	77	0.06*
Error	191	0.02

*significant at α=0.001

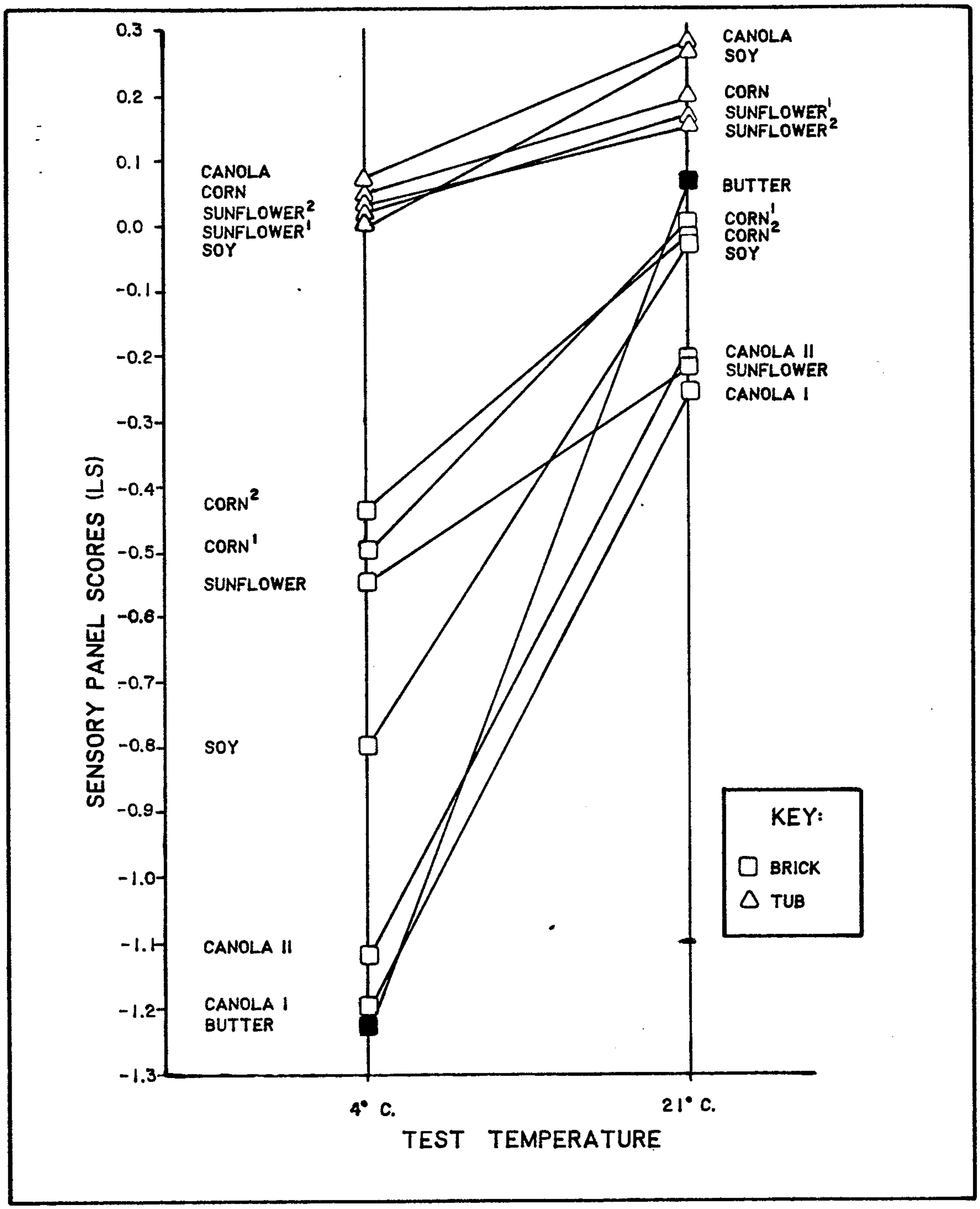

Figure 25: Spreadability of Tablespreads -- Spread X Temperature Interaction

The spread X temperature interaction (Figure 25) was again mainly contributed by the butter which was poorly spreadable at 4°C but the most spreadable of the bricks at 21°C. The sunflower brick contributed to the interaction by changing very little in spreadability, relative to the other bricks, between the two temperatures. The spread X panelist interaction was small relative to the other main effects and was caused by inversions of rank within market forms; all the panelists scored the bricks as less spreadable and the tubs as more easily spreadable. The panelist X temperature interaction (Figure 26) was mainly caused by one panelist who scored products at 4°C relatively less spreadable than the other panelists but scored products at 21°C as much more easily spreadable relative to the scoring of the other panelists. The third order interaction was minor and probably an accumulation of the second order interactions.

Comparisons among the tablespreads showed that the brick products at 4°C were the least spreadable, the tubs at 4°C and the bricks at 21°C were equally spreadable and the tubs at 21°C were the most spreadable (Table 20). The agreement between the means of the two samples of corn brick and sunflower tub suggested panel consistency. Variance herterogeneity would likely have been caused by the large variation in the scoring of the brick products at 4°C.

Comparisons among oil sources showed that the corn brick was significantly more spreadable than the other brick products, sunflower and soy brick and butter were more difficult to spread, but canola brick was significantly less spreadable than the other oil sources within the brick market form. Butter was equal in spreadability to the canola

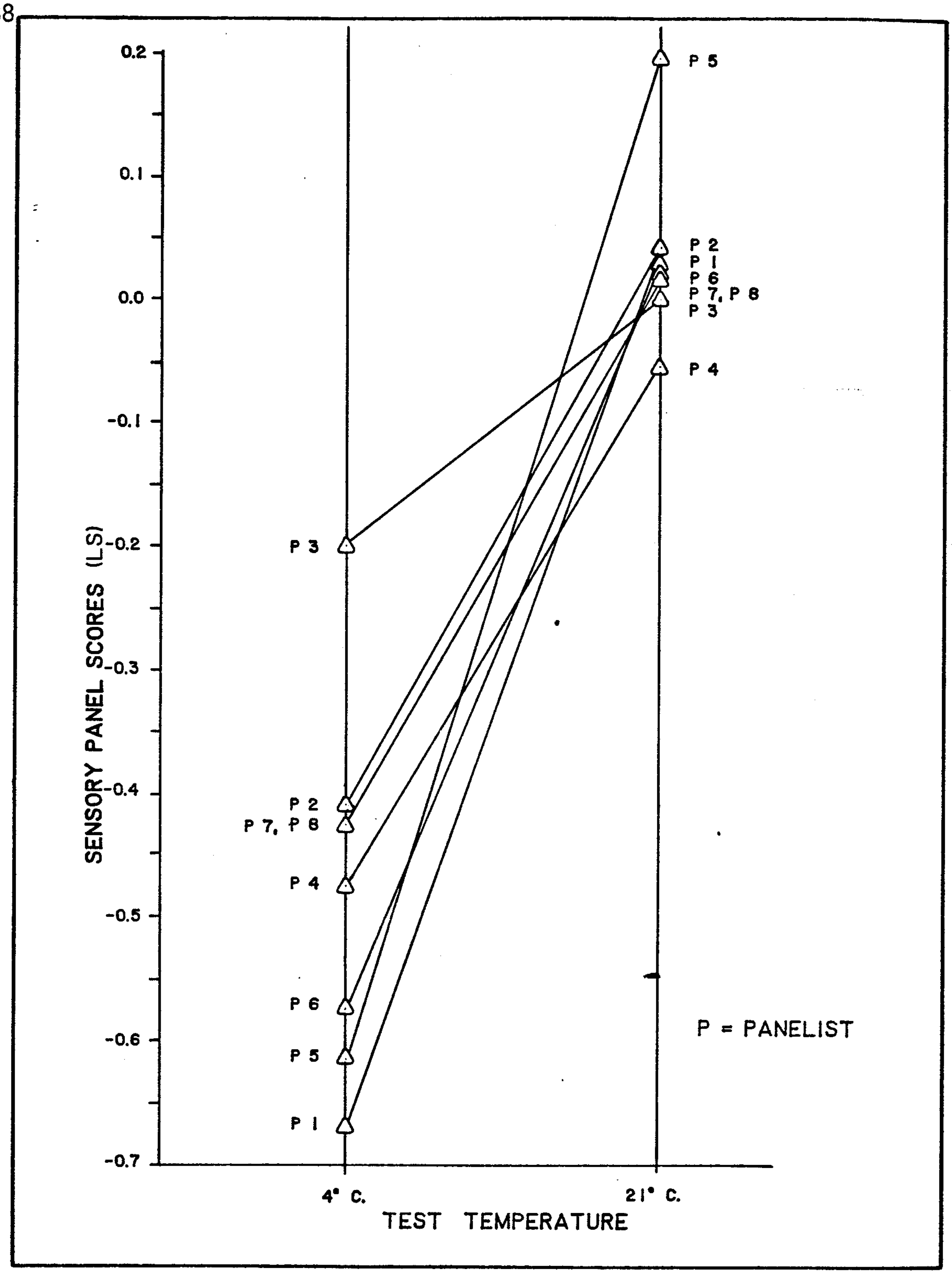

Figure 26: Spreadability -- Temperature X Panelist Interaction

TABLE 20

Spreadablity Assessments -- Comparisons Among Tablespreads

	LOG SENSORY SCORES[1] (LS)	
Product	Mean	S.E.M.
4°C		
Brick:		
Butter	-1.23 a	0.107
Canola I	-1.20 a	0.111
Canola II	-1.12 ab	0.122
Corn	-0.50 cd	0.072
Corn[2]	-0.45 cd	0.047
Soy	-0.80 bc	0.092
Sunflower	-0.55 cd	0.081
Tub:		
Canola	0.07 ef	0.026
Corn	0.04 ef	0.018
Soy	0.07 ef	0.019
Sunflower	0.02 ef	0.020
Sunflower[2]	0.03 ef	0.021
21°C		
Brick:		
Butter	0.06 ef	0.024
Canola I	-0.26 de	0.024
Canola II	-0.21 de	0.044
Corn	0.00 ef	0.023
Corn[2]	-0.02 ef	0.026
Soy	-0.04 ef	0.031
Sunflower	-0.22 de	0.044
Tub:		
Canola	0.29 f	0.022
Corn	0.19 f	0.024
Soy	0.27 f	0.030
Sunflower	0.16 f	0.019
Sunflower[2]	0.15 f	0.033

[1] n=16

[2] products were included in each sitting, therefore twice per replication

abc means within a column, followed by by the same letter are not significantly different α=0.01

TABLE 21

Comparison of Spreadability by Oil Source and Market Form

FACTOR		TREATMENT				
Oil Source	Brick:	Corn	Sunflower	Soy	Butter	Canola
	Mean	-0.24a	-0.38b	-0.42bc	-0.58c	-0.70d
	n	32	16	16	16	32
	Tub:	Soy	Canola	Corn	Sunflower	
	Mean	0.02a	0.13a	0.12a	0.09a	
	n	16	16	16	32	
Market Form			Brick	Tub		
	Mean		-0.44a	0.13b		
	n		160	160		

abc means, within a row, followed by the same letters are not significantly different at α=0.01

products at 4°C (Table 20), but the butter temperature interaction (Figure 25) resulted in butter being somewhat more spreadable than the canola bricks at 21°C; butter therefore had an overall better spreadability than the canola products. There was no oil source effect among the tub products (Table 21).

The comparisons between the market forms, shown in Table 21, supported the expectation that tub products were overall significantly more spreadable than brick products. Note that the fresh canola products were not available for the spreadability assessments (Figure 13), therefore no storage effect was tested for this parameter.

Analysis was also performed on the values assigned to the category scale (Table 22). The panelists assigned values only to those categories relevant to the samples they had just evaluated; the analysis was performed using a completely random model. The small error term in Table 22 suggested that further partitioning of the variance would not have been an advantage. The initial analysis was on each category-temperature combination making a total of 14 treatments; since multiple comparisons showed that there was no significant temperature effect, the means and s.e.m. for each category at both temperatures were pooled (Table 23).

Multiple comparisons sorted the categories of spreadability into three groups; C1 was significantly harder to spread than any other category, C3, C4 and C5 were not significatly different from each other, C7 was significantly softer than the ideal spreadability category, C4. C4, ideally spreadable was not significantly different from the firmer category or the next two softer ones, suggesting that the acceptable range was quite wide.

TABLE 22

Spreadability Categories -- Analysis of Variance

Source of Variation	d.f.	MS
Between categories	13	5.03*
Within categories	357	0.03

*Significant at $\alpha=0.001$

TABLE 23

Mean Values for Categories of Spreadability

Category	n	Mean	S.E.M.
C1. Too hard (will not spread)	51	-0.93 a	0.053
C2. Too hard, just barely spreadable	54	-0.47 b	0.024
C3. Hard but satisfactorily spreadable	58	-0.24 bc	0.002
C4. Satisfactory plastic and spreadable	64	0.00 cd	0.000
C5. Soft but spreadable	51	0.15 de	0.007
C6. Very soft, oily soaks into bread	50	0.26 de	0.010
C7. Very soft, almost pourable	43	0.42 e	0.025

abc means followed by the the same letter are not significantly different at α=0.01

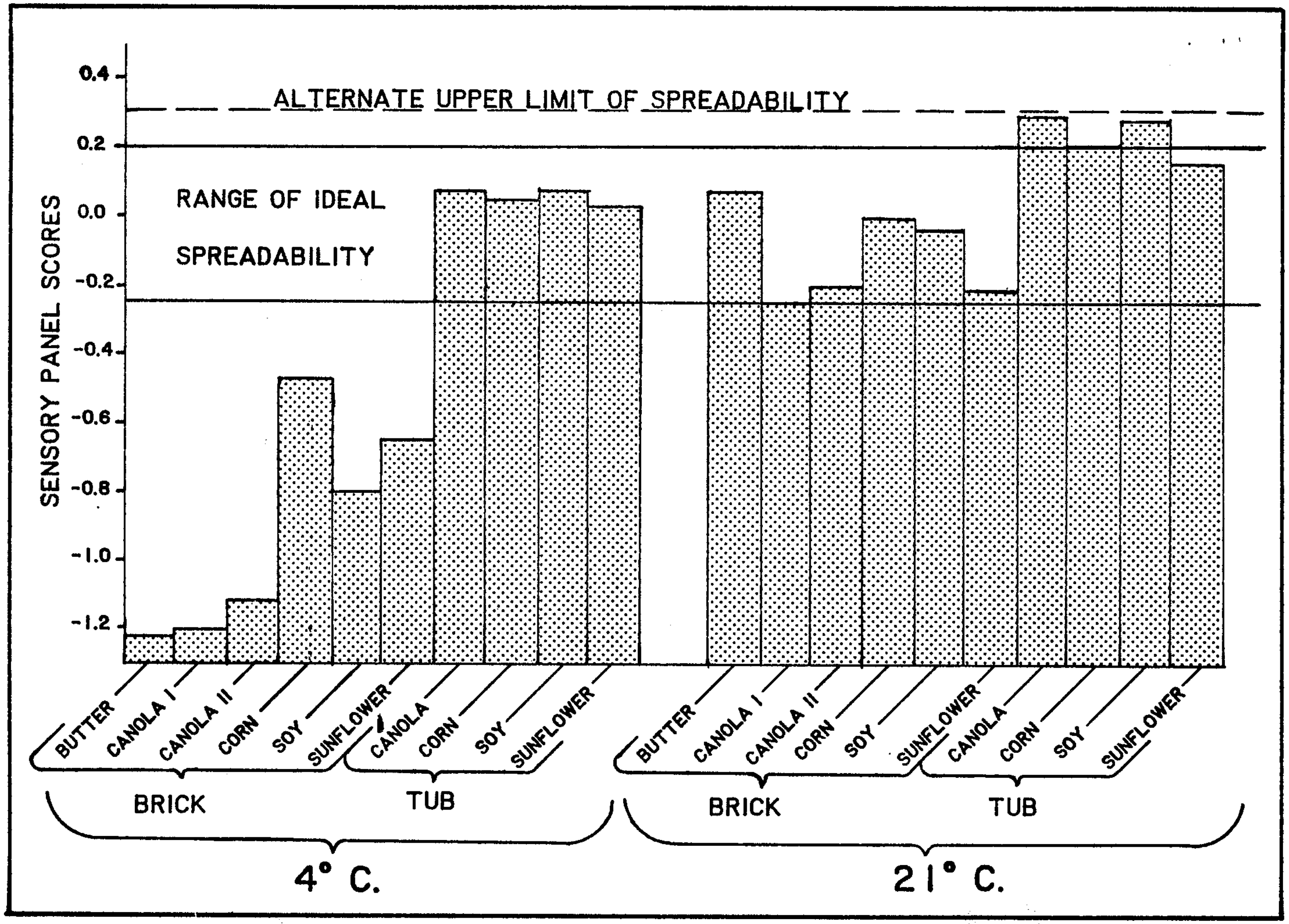

Figure 27: Classification of Tablespreads into Spreadability Categories

Figure 27 illustrates the application of the category scale to the spreadability scores of the products. A zone incorporating C3, C4 and C5 was considered to be ideally spreadable; the slashed line denotes the upper limit of C6 and represents an alternative limit for spreadability since it was not significantly different from C4 and C5 and was therefore still considered to be acceptably spreadable. The bricks at 4°C were considered too hard to spread, although corn and sunflower were in the barely spreadable range. The tubs at 4°C were in the range of ideal spreadability and the bricks at 21°C were equivelent to the 4°C tubs. The canola and sunflower bricks were barely classified as spreadable even at 21°C. The tubs at 21°C were beginning to encroach into the too soft categories but none of the products were found to be pourable, C7, or too soft to spread, by the panelists.

Mouthfeel Properties

1. Rate of Mouthmelt.

The analysis of variance for the rate of mouthmelt evaluation (Table 24) showed that there were significant differences within the main effects of spread, temperature and panelist; there was also significant interaction of spread with temperature, with panelist and temperature with panelist. The mean rate of mouthmelt at 4°C was 1.25 (the log of 18 seconds) and at 21°C was 1.08 (the log of 12 seconds). The significant panelist effect was not surprising, considering the nature of the test; slightly different body temperatures for example would contribute variability. Fortunately the panelist effect was not so great as to mask differences between the spreads. The spread X temperature interaction was less than in the previous tests and resulted from two and three place inversions within bricks only. The interaction of spread with panelist was a minor inversion of two products by a single panelist. The temperature X panelist interaction was of the same magnitude and nature as that observed in spreadability, one panelist using extreme values at each temperature (Figure 26).

Comparisons between tablespreads (Table 25) showed the same trend as the other textural assessments with one notable exception, butter at 4°C previously represented the extreme product, in this parameter it was the most rapidly melting of the bricks. Analogous to the other tests the bricks at 4°C required the longest time to achieve total melt, the tubs at 4°C and the bricks at 21°C were essentially equal and the tubs at 21°C melted the quickest, approximating the time for butter. Note that the multiple comparisons were performed at a larger α than the other tests to sort the products more clearly. Relaxation for the multiple comparison test was justifiable as this data did meet the homogeniety of variance assumption (Table 11).

Comparisons of the rate of mouthmelt among oil sources within the brick market form showed that the brick margarines generally took longer to melt that did the butter (Table 26). Within the tub products, the corn and sunflower products were the slowest to melt, soy intermediate and the canola tub melted the quickest. Testing the market form effect established that the brick products melted significantly more slowly than the tubs. The storage effect was significant; the fresh canola products melted significantly more slowly than the stored canola products. The very rapid melt of the stored canola tub product may have skewed the results of the storage effect test.

TABLE 24

Rate of Mouthmelt -- Analysis of Variance

Source of Variation	d.f.	MS
Spread	11	0.44*
Temperature	1	2.42*
Panelist	6	0.17*
Replication	1	0.01
S X T	11	0.02*
S X P	66	0.01*
T X P	6	0.15*
S X T X P	66	0.01
Error	167	0.006

*significant at α=0.001

TABLE 25

Rate of Mouthmelt Assessments -- Comparisons Among Tablespreads

Product	LOG SECONDS TO MELT[1] (LSm) Mean	S.E.M.
4°C		
Brick:		
Butter	1.26 abcd	0.026
Canola I	1.36 ab	0.026
Canola I F	1.40 a	0.039
Canola II	1.38 ab	0.036
Corn	1.30 abc	0.023
Soy	1.31 abc	0.017
Sunflower	1.34 ab	0.035
Tub:		
Canola	1.09 defg	0.019
Canola F	1.16 cdef	0.030
Corn	1.15 cdefg	0.024
Soy	1.12 defg	0.023
Sunflower	1.14 cdefg	0.027
21°C		
Brick:		
Butter	1.04 efgh	0.033
Canola I	1.22 abcd	0.034
Canola I F	1.21 bcde	0.021
Canola II	1.26 abcd	0.026
Corn	1.13 defg	0.021
Soy	1.11 defgh	0.021
Sunflower	1.25 abcd	0.040
Tub:		
Canola	0.78 i	0.054
Canola F	1.04 efgh	0.027
Corn	1.01 fgh	0.039
Soy	0.94 hi	0.040
Sunflower	0.98 gh	0.041

[1] n=14

abc means followed by the same letter are not significantly different α=0.05

TABLE 26

Rate of Mouth Melt Comparisons Among Oil Source, Market Form and Storage

FACTOR		TREATMENT				
Oil Source	Brick:	Canola	Sunflower	Corn	Soy	Butter
	Mean	1.30a	1.29a	1.21ab	1.21ab	1.15b
	n	28	14	14	14	14
	Tub:	Corn	Sunflower	Soy	Canola	
	Mean	1.08a	1.06a	1.03ab	0.94b	
	n	14	14	14	14	
Market Form			Brick	Tub		
	Mean		1.25a	1.08b		
	n		112	112		
Storage			Fresh	Stored		
	Mean		1.20a	1.11b		
	n		56	56		

abc means within a row, followed by the same letter are not significantly different $\alpha=0.01$

2. Graininess.

Using the frequency with which graininess was observed in the products (Table 27) χ^2 tests for independence of graininess for spread, temperature, oil source, market form and storage effect were performed. Significance was declared if $\alpha < 0.01$.

It was observed that graininess was dependent on the type of spread; the canola and sunflower products tended to have a higher frequency of graininess observations than the other products. The observation of graininess was also dependent on temperature; there was a significantly greater likelihood of observing graininess in samples at refrigerator temperatures than in room temperature samples. The oil source effect results were as implicated by the results of the spread effect; there was a significant relationship of graininess to oil source. When the canola and sunflower products were removed from the analysis the relationship was eliminated. The brick market forms were significantly more likely to have grain observed in them than were the tub products. Results of the frequency of graininess observation for the storage effect showed no significant relationship when the fresh and stored brick and tub products were pooled; however, when analyzed separately the stored canola brick was significantly more grainy than the fresh brick. No significant storage effect was noted between fresh and stored tub products.

The estimated amount of graininess agreed with the frequency data; if more graininess was present in a product there was a greater likelihood that the panelists would have perceived it.

TABLE 27

Observed Frequency and Estimated Quantity of Graininess in Tablespreads

	4°C			21°C		
Product	Frequency[1]	Mean Amount[2]	S.E.M.	Frequency[1]	Mean Amount[2]	S.E.M.
Brick:						
Butter	0	--	--	0	--	--
Canola I	9	3.2	0.50	7	2.8	0.77
Canola I F	4	0.8	0.38	3	0.6	0.32
Canola II	7	1.4	0.40	4	0.7	0.34
Corn	1	0.2	0.16	1	0.5	0.48
Soy	2	0.3	0.20	1	0.2	0.20
Sunflower	10	5.4	0.19	10	4.6	0.44
Tub:						
Canola	0	--	--	0	--	--
Canola F	6	1.0	0.33	0	--	--
Corn	0	--	--	0	--	--
Soy	0	--	--	0	--	--
Sunflower	10	3.2	0.59	8	2.8	0.68

[1] maximum possible frequency=10
[2] n=10

TABLE 28

Estimated Size of Particles in Tablespreads

	4°C			21°C		
Product	n	Mean Size	S.E.M.	n	Mean Size	S.E.M.
Brick:						
Canola	9	3.5	0.71	7	5.1	0.25
Canola I F	4	5.5	0.38	3	4.3	0.90
Canola II	7	5.6	0.27	4	4.9	0.70
Corn	1	6.0	--	1	0.6	--
Soy	2	6.0	0.00	1	0.2	--
Sunflower	10	1.1	0.38	10	1.6	0.39
Tub:						
Canola F	6	5.9	0.08	0	--	--
Sunflower	10	2.5	0.67	8	2.5	0.50

For those products in which graininess was detected, the size of the particles was estimated (Table 28). The line scale for estimating size of grain was truncated at the right hand side when panelist found lumpy products at 4°C; the graininess thus recorded for the corn, soy and fresh canola products was probably a function of uneven melt or emulsification factors rather than graininess per se. Accepting the results from the amount of grain assessments previously reported, in which canola and sunflower products were implicated, it was observed that the graininess in sunflower products was more frequently described as small chalky particles, and the canola products were described as having relatively larger particles in the grainy range.

Prediction of Spreadability

To establish which parameter, firmness, work to soften or rate of mouthmelt and which assessment, sensory or texturometer could best be used to predict spreadability a series of coefficients of determination (r^2) were calculated (Table 29). Log firmness, from both sensory and texturometer assessments were highly correlated with the antilog of spreadability, $r^2 = 0.93$ and 0.94 respectively; sensory log work to soften and sensory log rate of mouthmelt also correlated well with antilog of spreadability, each having an r^2 greater than 0.92.

Those independent variables with $r^2 > 0.90$ were considered first for incorporation into equations to predict spreadability. Firmness was selected as the primary parameter because it had a high correlation with spreadability, it is simple to measure and it approximates the penetration tests reported in deMan et al. (1979), Dixon and Parekh (1979) and

TABLE 29

Coefficients of Determination (r^2) for Spreadability with Firmness, Work to Soften and Rate of Mouth Melt

Independent Variables	Log Spreadability (LS)	Antilog Spreadability (AS)
Sensory:		
Firmness (LSf)	0.869	0.933*
Antilog Firmness (ASf)	0.852	0.532
Work to Soften (LSw)	0.785	0.926*
Antilog Work to Soften (ASw)	0.930*	0.750
Rate of Mouth Melt (LSm)	0.678	0.924*
Antilog Rate of Mouth Melt (ASm)	0.766	0.921*
Texturometer:		
Firmness (LTUf)	0.859	0.940*
Antilog Firmness (ATUf)	0.921*	0.682
Reduction in Hardness (LTUr)	0.663	0.801
Antilog Reduction in Hardness (ATUr)	0.883	0.650

*variables incorporated into multiple regression equation

Board et al. (1980). The texturometer firmness was more strongly correlated with sensory spreadability than the sensory firmness; the values for the latter test at 21°C were estimated from the texturometer measurements, making it a less reliable data set. Although the texturometer reduction in firmness did not correlate as well with spreadability as did the sensory work to soften, it was included in the predictive equations as a replacement for the latter since it is easy to measure, being a simple extension of the texturometer curve.

The multiple regressions developed (Table 30) obtained up to 97% predictability. The texturometer antilog reduction in firmness contributed more to the predictability of log spreadability than did the sensory antilog work to soften; as discussed in the work to soften results the sensory work to soften assessment may have been directly related to firmness and therefore would not contribute additional information. Adding senory log rate of mouthmelt to texturometer log firmness added 3% more to spread predictability than did the addition of either of the work to soften assessments. As shown in Table 30 there was very little advantage in combining three independent variables into the prediction equation.

TABLE 30

Equations for the Prediction of Spreadability

Predictive Equation	r_1^2	r_2^2	r_3^2	Mr^2
LS=0.307 - 0.059ATUf - 0.009ASw	0.921	0.014	--	0.935
LS=0.242 - 0.096ATUf - 0.215ATUr	0.921	0.032	--	0.952
AS=1.99 - 0.909LTUf - 0.565LSw	0.940	0.008	--	0.947
AS=1.28 - 1.31LTUf - 0.095LTUr	0.940	0.002	--	0.942
AS=3.10 - 0.826LTUf - 1.69LSm	0.940	0.031	--	0.971
AS=3.23 - 0.658LTUf - 1.59LSm - 0.217LSw	0.940	0.031	0.001	0.971
AS=3.01 - 0.678LTUf - 1.70LSm - 0.098LTUr	0.940	0.031	0.002	0.973

r_1^2=coefficient of determination for first independent variable

r_2^2=contribution of the second independent variable to r^2

r_3^2=contribution of the third independent variable to r^2

Mr^2=coefficient of determination for the equation

DISCUSSION

Fatty Acid Composition

The fatty acid compositions of the margarines in this study were generally consistent with the values reported by Sahasrabudhe and Kurian (1979). For margarines which did not specify oil source those authors distinguished canola based products by low levels of C16:0, less than 10%, and soy products by the presence of C18:3. The results of the present study, in which oil source of the products was known, supported those generalizations with one exception, sunflower products also contained less than 10% C16:0. Sunflower margarine was not available in the spring of 1978 when Sahasrabudhe and Kurian (1979) obtained the products for their study.

The values for trans C18:1 reported by Sahasrabudhe and Kurian (1979) were obtained by GLC using the same type of column as that used in this study and were comparable to the values reported here, that is, 23-39% in the brick margarines and 10-28% in tub margarines. Canola products in both studies contained the highest levels of trans C18:1. Sahasrabudhe and Kurian (1979) reported 1-2% cis-trans, trans-cis C18:2 in only three products but reported up to 3% trans-trans C18:2 in almost one-half of the 95 products they evaluated; in the current research 1-5% cis-trans, trans-cis was recovered in canola and soy bricks and the canola tub (Table 6). No measure of trans-trans was possible in this study as this fraction is believed to have been recovered with the cis

C18:1 fraction. Other researchers using different columns (Parodi, 1976; Heckers and Melcher, 1978) have commented on the lack of separation of trans-trans C18:2 from the cis C18:1 fraction. Considering the similarity of the method used in this study with that used by Sahasrabudhe and Kurian (1979) and the different interpretations which resulted it is suggested that caution must be used when considering the type and amount of C18:2 isomers reported in hydrogenated oils.

The range of total trans, 16-46% obtained by IR in the current research (Table 6) was within the 0-50% range reported by Beare-Rogers et al. (1979) using the same method. The greater range of total trans observed in the latter study would probably have been a function of sample size and selection; Beare-Rogers et al. (1979) evaluated 50 brands of margarine available in the Ottawa area, the current research used only four brand name products. All three studies found that trans isomers were predominately in the C18:1 fraction, that brick products tended to have higher trans levels than tub products and that high levels of trans isomers tended to be related to low levels of cis-cis C18:2.

The range in the values for cis-cis C18:2 reported in this study for brick products, 4-39%, was somewhat smaller than the range of 6-37% reported by Beare-Rogers et al. (1979); none of the brick products evaluated by Sahasrabudhe and Kurian (1979) had more than 10% cis-cis C18:2. The higher values observed by Beare-Rogers et al. (1979) could have been a function of sampling, as stated above; also those authors used lipoxidase analysis as opposed to the GLC technique used here. The low values reported by Sahasrabudhe and Kurian (1979) would have been possible if no corn oil products were included, since only corn and sunflower brick margarines in the current study had levels of cis-cis C18:2 greater than 10%; the actual values were 30 and 28% respectively, soy brick had 12% cis-cis C18:2. Sahasrabudhe and Kurian (1979) did include two semi-solid bricks under a separate listing, a corn product containing 33% cis-cis C18:2 and a soy product containing 9%.

The results of the cis-cis C18:2 analysis in tubs showed better agreement among studies with ranges of 16-45%, Beare-Rogers et al. (1979), 2-46%, Sahasrabudhe and Kurian (1979) and 4-42% cis-cis C18:2 for the tub products analyzed in this study (Table 6). The canola products again had the lowest levels, less than 10% cis-cis C18:2, soy approximately 33% and corn greater than 40% which agreed with the values reported by Sahasrabudhe and Kurian (1979). The sunflower tub product in this study was comparable to the corn products.

In terms of the recommendations put forward by the ad hoc commitee on the composition of special margarines to the Health Protection Branch (Davignon et el, 1980), the canola products, brick and tub, barely met the minimum suggested requirement for 5% cis-cis C18:2 in margarine products (Table 31). Corn and sunflower products of both market forms and soy tub could safely make label claims for levels of cis-cis C18:2, all having apparent levels greater than 25%. None of the brick margarines met the suggested requirement for less than 40% saturated plus trans fatty acids although corn and sunflower were close with 44% and 41% respectively. Butter with 4% cis-cis C18:2 and almost 70% saturates plus trans would never meet the minimum requirements under consideration for margarine products.

TABLE 31

Summary of the Fatty Acid Fractions Relevant to Nutritional Consideration[1]

	Cis-Cis C18:2	Total Trans[2] + Saturates
Brick:		
Butter[3]	4%	69%
Canola[4]	5%	51%
Corn	30%	44%
Soy	11%	51%
Sunflower	28%	41%
Tub:		
Canola	5%	38%
Corn	42%	29%
Soy	33%	34%
Sunflower	42%	32%

[1] values from Table 6

[2] min values reported in Table 6

[3] Smith *et al.*, 1978

[4] mean of products from both manufacturers

The relative amounts of the high melting point fraction of trans and saturated fatty acids were reflected in the SFI and DSC melt information (Figure 28 a and b). Products containing a higher proportion of trans plus saturated fatty acids, that is the brick products, had a higher solids content at 10°C than did the unsaturated tub counterparts. The DSC melt pattern showed that the more unsaturated tub products had already undergone 70-80% of their total melt below 4°C, whereas the more saturated brick products had less melt below 4°C but proportionately more melt between 4°C and 20°C. The effect of fatty acid compostion and melt properties on textural characteristics was as expected (Figure 28 c and d); products with higher levels of trans and saturated fatty acids were firmer and less easily spread at 4°C.

The recommendations by the ad hoc committee regarding levels of trans plus saturates will necessitate the production of softer products. The trend for panelists to evaluate the softer products as spreadable suggested that the new products would have acceptable performance characteristics. The canola products would have difficulty consistently meeting the suggested recommendation regarding a minimum level of 5% cis-cis C18:2, and the brick canola products exceeded the maximum suggested level of 40% trans plus saturated fatty acids by 11%. Some changes in the production of margarines from canola oils will be necessary. The canola brick products, from both manufacturers were firmer and less spreadable than other products in that market form suggesting that a reduction in hydrogenation, as indicated by the fatty acid compostion, would be beneficial for their performance characteristics.

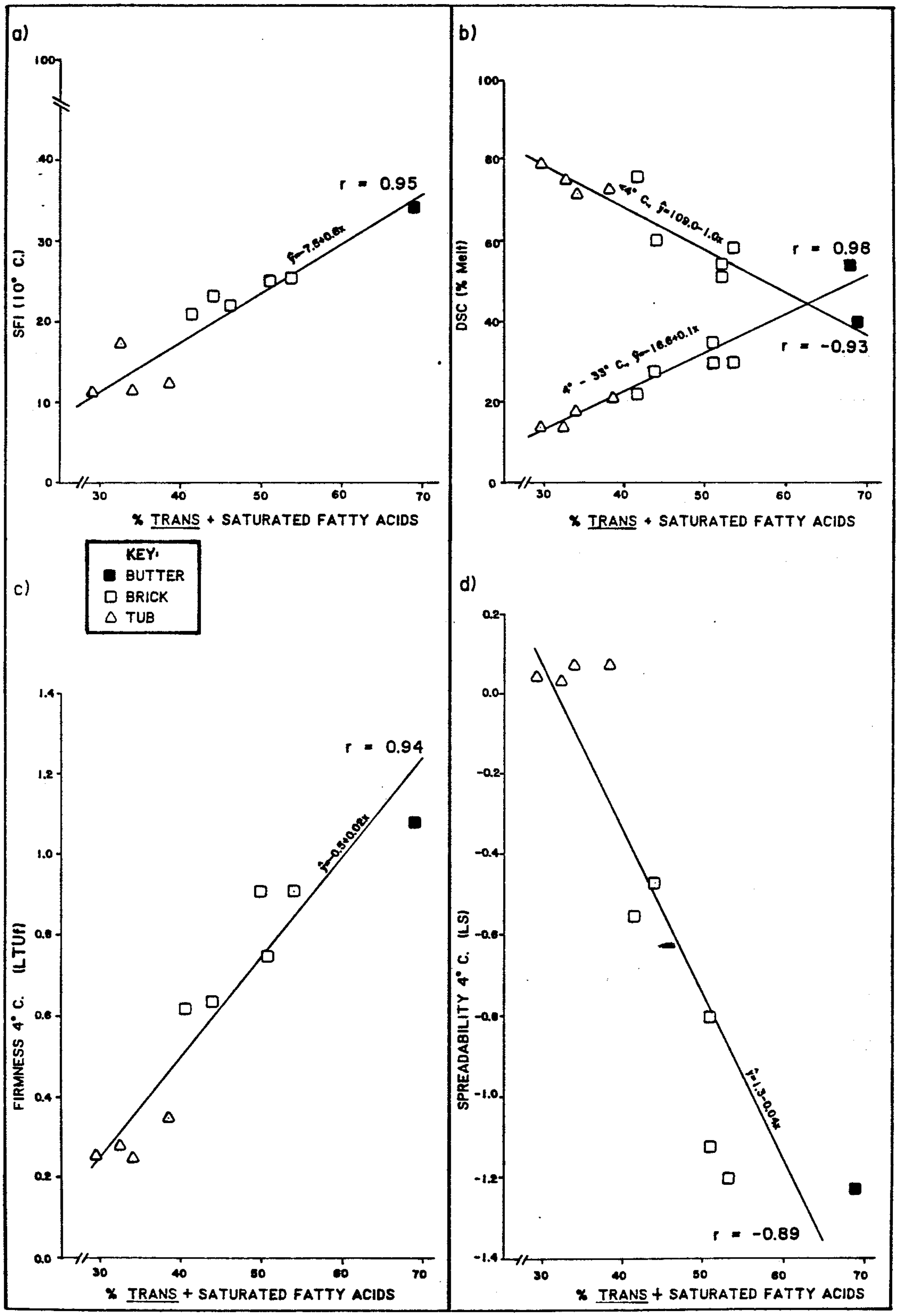

Figure 28: The Effect of Fatty Acid Composition on the Melting Properties and Textural Characteristics of Tablespreads

Graininess in tablespreads was reportedly promoted by high levels of C18 fatty acids and inhibited by the presence of C16:0 fatty acids (Weinberg, 1972; Loewen, 1980). When deMan (1978) studied graininess in hydrogenated canola products, it was observed that oils with higher trans fatty acid content developed graininess more readily than did oils with lower trans levels, consistent with the packing phenomenom explained by Chapman (1962). C18:0 plus trans C18:1 were therefore classified as promotors of graininess and other C18 fatty acids and C16:0 were classified as inhibitors of graininess. The high ratio of promotors over inhibitors, greater than 75%, as shown in Table 32, could explain the graininess observed in canola brick products; however, it was not adequate to explain the smaller chalky particles observed in the sunflower products. Graininess in sunflower products was better explained by the high levels, greater than 90%, of total C18 fraction. Both canola and sunflower oils were low in C16:0; Merker et al. (1958) found that adding 20% cottonseed oil, thus increasing C16:0 in soy oils by 2.5%, was adequate to prevent graininess in that product.

More information is required on crystal polymorphism and triglyceride packing with the goal of explaining the different mechanisms which may be operating to cause the graininess observed in canola products and the chalkiness in sunflower products.

TABLE 32

The Effect of Fatty Acid Compostion[1] on the Development of Graininess

	Total C18	Promoters[2] (P)	Inhibitors[3] (I)	Ratio P/I	C16:0
Brick:					
Butter	38.8	11.5	27.3	0.42	28.0
Canola I	85.6	41.5	45.7	0.91	5.7
Canola II	85.5	37.5	47.8	0.78	8.3
Corn	88.0	32.2	56.1	0.57	11.0
Soy	87.2	36.9	50.1	0.74	10.5
Sunflower	91.2	33.4	55.6	0.60	6.5
Tub:					
Canola	86.5	27.2	60.3	0.45	4.1
Corn	87.9	17.6	69.6	0.25	11.1
Soy	87.5	21.1	66.5	0.32	10.7
Sunflower	91.6	24.4	65.2	0.37	6.6

[1] values from Table 6, except butter which was from Smith *et al.*, 1978

[2] C18:0 + *trans* C18:0

[3] other C18 fatty acids

Physical Properties

Solid Fat Index

The SFI values reported as typical for products marketed in the late 1960's (Table 3) by Wiedermann (1968) corresponded to the upper limit for the SFI values of the products evaluated in the current study (Table 7); providing indirect evidence of a market trend toward preference for softer products. The brick products reported in this study all had lower SFI values at 10°C and at 21.1°C, 16-26 and 12-16 respectively, than did the products evaluated by deMan et al. (1979), 28-36 and 17-18 at 10°C and 20°C respectively. Of particular interest was the M1 product in the deMan at al. (1979) study which corresponded to the corn brick product of this study (deMan, 1980); the SFI reported by deMan et al (1979) was 10 units higher than the values supplied by the manufacturer and reported here. The SFI values reported for tub products were comparable in both studies. More specific comparisons were not possible since deMan et al. (1979) used temperatures of 5, 10, 15, 20 and 25°C for evaluation and the temperatures used in this study were the standard AOCS temperatures of 10, 21.1 and 33.3°C.

Weiss (1970) suggested that products with SFI values less than 28 would be spreadable; in the current study products with SFI values of 20-34, the brick margarines and butter at 4°C, were considered to be barely spreadable or too hard to spread as shown in Figure 29 a. Products with SFI values of 10-16, tubs at 10°C and bricks at 21°C, were considered to be spreadable by the panel; this was in agreement with the SFI range of 10-20 established by the panel which was used in the work

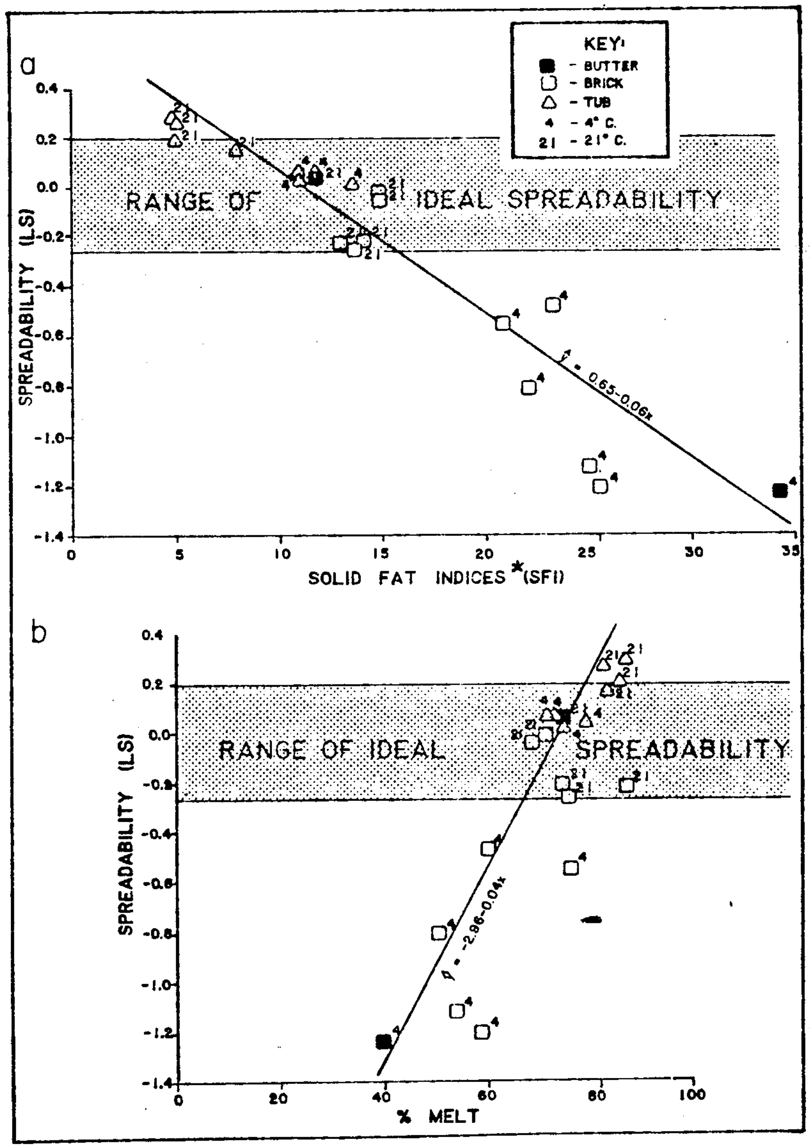

Figure 29: The Relationship of Solid Fat Index and % Total Melt with Sensory Scoring of the Spreadability of Tablespreads

*SFI at 4°C was not available, values at 10°C were substituted done by deMan et al. (1979). The latter study reported that products with an average SFI value of 7.1 were considered by the panel to be too soft to spread. How this information was extrapolated from the evaluation carried out by those authors was not explained; the spreadability scale used in the research did not have a category labelled explicitly as 'too soft to spread'. In the current study products with SFI values of 5 were still not scored in the softest category, C7, as shown by the alternate upper limit of spreadability in Figure 27 Unfortunately, again no category was defined as 'too soft to spread' therefore information regarding how soft was too soft was not obtained.

Differential Scanning Calorimetry

The eutectic melt peaks of the products were similar to those described by Sherbon and Dolby (1972) and shown in Figure 5, only in this study the peaks were less distinct (Figure 18); the earlier study used a 3°C faster heating rate which may have sharpened the peaks. The thermogram of the butter in the Sherbon and Dolby (1972) study showed one large area of continous melt between 0°C and 35°C, the butter in this study had three melt areas between 0°C and 35°C more closely agreeing with the butter fat thermograms obtained by Taylor and Norris (1977) and deMan et al. (1979) (Figure 4). The general interpretations relating shape of the thermograms to performance characteristics were consistent with those reported in the latter two studies. Butter had little or no melt below 4°C and was therefore hard at refrigerator temperature; brick margarines had some melt in the low tempeature range making them generally softer than butter but still borderline in spreadability; large areas of melt below 4°C, more than 75% of total melt, made the thermograms of tub margarines distinctive. It is this high degree of melt at low temperatures which confers the unique spreadability characteristics for which tub margarines are noted (Taylor and Norris, 1977; Anon, 1979). The area of melt between 4°C and 20°C was the equalizer such that at 21°C minor textural differences existed between butter and the margarines and between the brick and tub market forms. Products which had achieved 70-85% of total melt were scored as being desirably spreadable by the panelists (Figure 29 b).

The average heat of fusion, 35 mcal/mg, obtained for the products in this study was consistent with the average heat of fusion for fat assumed by Bentz and Breidenbach (1969), Miller et al. (1969) and Walker and Bosin (1971); the range of 30-41 mcal/mg between fats suggested that the average value may not be applicable to all fats.

The heat of fusion should reflect the crystal form present, that is β having a higher melting point and heat of fusion than β' (Chapman, 1971); if the later run of the canola I product had had a higher heat of fusion this might have indicated polymorphism and crystal growth over storage, however the expected change in heat of fusion was not observed (Table 8).

There is a need to establish if real differences exist among oil sources regarding heats of fusion and to develop correction factors for the increase in heat of fusion with melting point. Such information is necessary before DSC can have more widespread application to lipid research.

Mouthmelt is hypothesized to be a function of the amount of solids at 33°C and the rate of melt of that residual fraction (Weiss, 1970;

Haighton, 1976). Butter had the highest SFI, a value of 6, at 33°C (Table 7), and the second lowest melt end point, 40°C (Figure 20); this combination of solid content and quick melt may account for the pleasant mouthmelt sensation of butter. If so the sunflower products, which also had low melt end points, 38-49°C, should also have had desirable meltdown characteristics. This hypothesis was not not substantiated by the time to melt data however, sunflower products were grouped as one of the more slowly melting of the oil sources (Table 26). Further research to establish the relationship of SFI, heats of fusion and mouthmelt are necessary.

Textural Assessments

The sensory panel scoring of the fimness of tablespreads has a high correlation with the texturometer measurement of firmness, $r^2 = 0.98$ and 0.90 at 4°C and 21°C respectively, suggesting that both instruments were measuring the same quality in the samples. The assessment of the work to soften quality of tablespreads as measured by the sensory panel and the texturometer did not correlate as well, $r^2 = 0.69$. The panel task was defined as the effort to work the sample to a predetermined end point, whereas the texturometer values were defined as the reduction in firmness of the tablespreads after a fixed amount of work, one down stroke of the plunger. Haighton's (1965) definition of work softening was analogous to the definition of the texturometer assessment of reduction in firmness; after obtaining an initial hardness measurement the samples were forced through an extruder thus receiving a fixed amount of work, the hardness was then remeasured. Haighton (1965) concluded from his research that butter did not work soften as extensively as did margarine of equal initial hardness; there was less reduction in firmness of the butter sample. He then went on to explain that since margarine was more susceptible to softening, it would be perceived as more spreadable than butter. In the current research no such oil source effect was noted; canola bricks were equal to the butter in firmness at 4°C (Table 13), exhibited the same amount of reduction in firmness at 4°C (Table 17) and were equally difficult to spread at 4°C (Table 20). Even though the butter and canola bricks were equally difficult to spread at 4°C, the butter X temperature interaction provided butter with a significantly better spreadability than that of the canola bricks when averaged across both temperatures (Table 21).

Sensory panel assessments of spreadability (AS) could be predicted adequatly by the texturometer firmness measurement (LTUf), r^2 = 0.94, (Table 29); products with firmness values in the range of -0.14 LTUf to 0.56 LTUf would be spreadable, as shown in Figure 30. The texturometer firmness alone was a better predictor of spreadability than the hardness assessment by cone penetration discussed by deMan et al. (1979), r^2 = 0.57, and was better than the combined values of hardness and work softening which Haighton (1965) used in a spreadability index equation. The spread predictability discussed in the current research using texturometer firmness was comparable to that obtained by Dixon and Parekh (1979), who obtained a predictability of r^2 = 0.94 of sensory panel assessments of spreadability with cone stress index obtained by cone penetration.

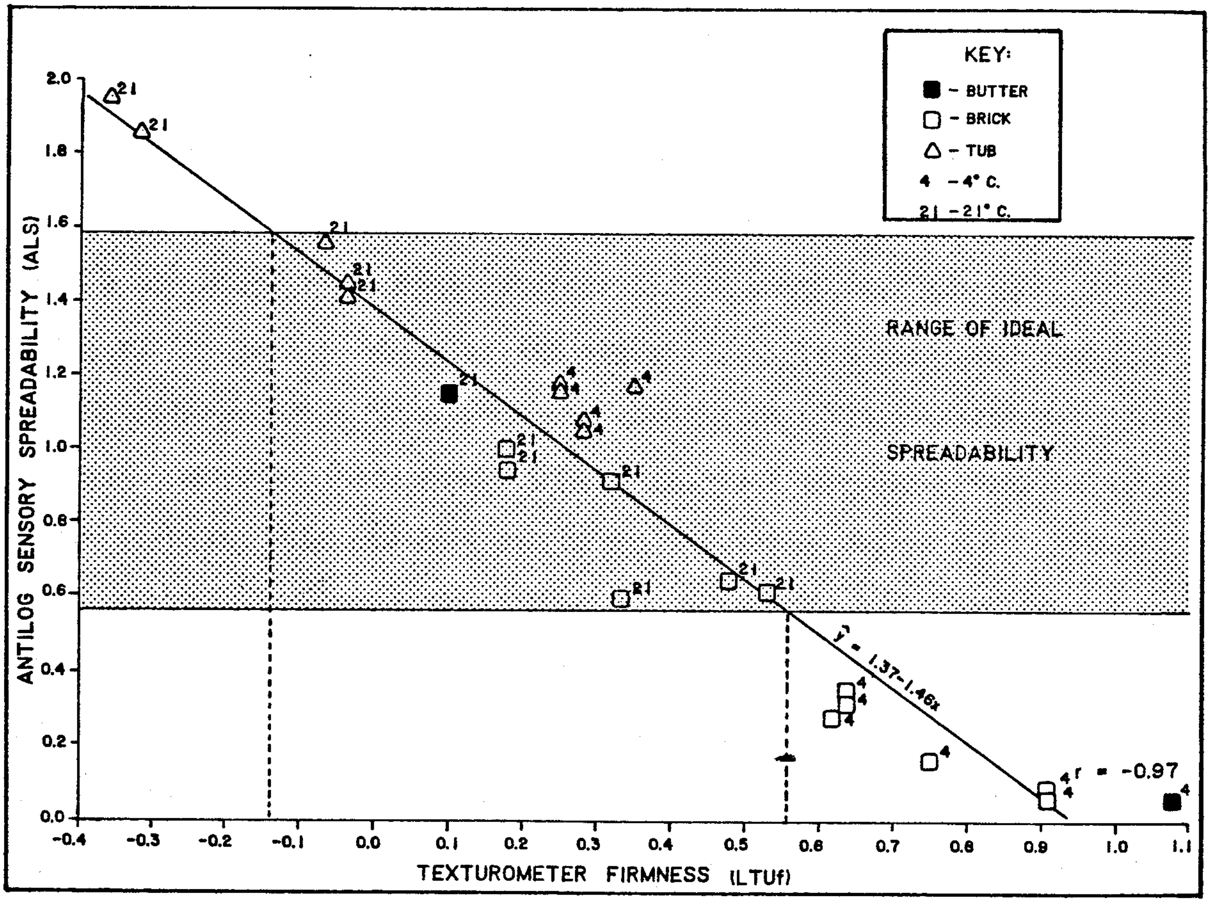

Figure 30: Relationship of Firmness as Measured by the Texturometer with Sensory Panel Evaluations of Tablespread Spreadability

The addition of a work to soften parameter, either that obtained from the sensory panel or the texturometer did not add appreciably to the prediction of spreadability already obtained by the texturometer firmness (Table 30); the addition of the values from the rate of mouth-melt assessment to the texturometer firmness contributed an additional 3% to the prediction of spreadability. However if a sensory panel is available for such an assessment they might be better utilized as an instrument to directly measure the spreadability of tablespreads. The texturometer firmness was a relatively quick and simple measurement from which to predict the spreadability properties of tablespreads.

For the evaluation of all textural parameters there was a significant temperature effect, however the relative ranking of the products was fairly consistent between temperatures with one notable exception, butter displayed interaction with temperature (Figures 21, 23, and 25). The butter X temperature interaction was also noted by deMan et al. (1979). The interaction of butter with temperature has been attributed to the extreme change in solid fat content between 4°C and 21°C (Taylor and Norris, 1977); the butter in the current research dropped 22 units in this temperature range, as compared to the average drop in SFI of 9 units for the brick margarines between 10°C and 21°C (Table 7). The butter did not display the noted interaction when the rate of mouth-melt was measured, it was quicker to melt than the other bricks at 4°C and at 21°C.

Using two temperatures for the testing provided a wider range of values from which to establish the relationship between the sensory panel assessments and the corresponding texturometer assessments and to establish the relationship between the parameters evaluated. If testing was to be done at only one temperature, 21°C would be preferred over 4°C since the former established a wider range of values than did the latter; this tendency was noticable in the evaluations of the tub products (Figure 21, 23, 25).

There was a consistent significant difference between market forms for all the parameters tested; bricks were significantly firmer (Table 14), significantly more resistant to work softening (Table 18), significantly more difficult to spread (Table 21), significantly slower to melt (Table 26) and significantly more likely to have graininess observed in them than were the tub products.

Comparisons between species could only be made within market form which prohibits generalizations; the canola brick products, for example, were the firmness of the brick products at 21°C but the corresponding tub product was the softest of its market form (Table 13). Also recall that oil source comparisons were confounded by the manufacturer effect (Figure 12).

The comparison between the storage effects on canola products did not support the findings of extreme hardness reported by deMan (1978); the latter study observed that cyling temperature over storage considerably promoted the development of grain in canola fats and increased the hardness as measured by cone penetration. The relatively stable storage conditions of the products over the experimental period of the current study may not have prompted the development of crystals to the same extent as that observed in the storage study performed by deMan (1978).

CONCLUSIONS

Fatty Acid Composition

The corn and sunflower products of both market forms and the soy tub product were able to meet the current criteria for a label claim for levels of cis-cis C18:2, that is they contained more than 25% of their fatty acids as cis-cis,9-12 octadecadienoic acid; none of the brick products meet the proposed requirement for levels of less than 40% trans plus saturated fatty acids. The canola products contained the lowest levels of cis-cis C18:2 and the highest levels of trans fatty acids. Increasing the levels of C16:0 in canola and sunflower products may minimize the tendency of these products to develop a coarse texture.

Physical Properties

Products with SFI values of less than 17 were considered to be ideally spreadable by the panel; the tub market form at 4°C and the brick products at 21°C tended to have SFI values in the spreadable range. The application of DSC to the products provided comparable information to that obtained by SFI; values for partial heats of fusion, expressed at % of total melt showed, that tub products underwent 70% of their total melt in the temperature range below 4°C thus accounting for the reduced SFI at 10°C and the spreadability characteristic of these products.

Textural Assessments

The products provided a range of performance characteristics, from very hard, unspreadable bricks at 4°C to soft, easily spreadable tub product at 21°C. The canola bricks scored consistently firmer, less spreadable and slower to melt than the other margarine products of the same market form. Graininess and chalkiness were perceived in the canola and sunflower products, respectively, by the panelists; whether graininess affected the mechanical parameters seems in doubt since no storage effect for firmness of canola products was detected by the texturometer assessment. Texturometer assessment of firmness provided excellent predictability for panel scoring of the spreadability parameter of tablespreads. The work to soften parameter, assessed either by the panel or the texturometer, did not provide the additional information expected regarding spreadability. There was a significant temperature effect for all parameters, however butter displayed a more extreme interaction with temperature than did the other products.

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Appendix A

PRODUCTS EXAMINED

Bricks:

Canola I

West - Hydrogenated vegetable oil 80%, moisture not more than 16%, salt 2.5%, milk solids 1.4%, vegetable lecithin 0.2%, vegetable mono and di-glycerides 0.1%, sodium benzoate 0.1%, artificial flavor and color, Vitamin A palmitate (3525 IU per 100 g), Vitamin D_2 (600 IU Vitamin D per 100 g).

Canola II

Experimental product - no label information was available.

Corn

Fleischmann's - 3,525 IU Vitamin A, 600 IU Vitamin D per 100 g, Liquid corn oil 41%, hydrogenated corn oil 39%, moisture 16%, salt 2%, skim milk powder 1.4%, lecithin 0.2%, vegetable mono and di-glycerides 0.1%, sodium benzoate 0.1%, artificial flavor and color, Vitamin A palmitate, Vitamin D.
Label Claim - 27% polyunsaturates, 18% saturates, 51% liquid corn oil.

Soy

Blue Bonnet - 3,525 IU Vitamin A, 660 IU Vitamin D per 100 g, Hydrogenated vegetable oil 80%, may contain palm oil, moisture 16%, salt 3%, skim milk powder (may contain whey powder) 1.4%, lecithin 0.2%, vegetable mono and di-glycerides 0.1%, sodium benzoate 0.1%, artificial flavour and color, Vitamin A palmitate, Vitamin D.

Sunflower

Achieve - Sunflower oil 80% (liquid sunflower oil 42% hydrogenated sunflower oil 38%), salt 2%, skim milk powder 1.4%, sorbitan tristearate 1.0%, vegetable lecithin 0.1%, vegetable monoglycerides 0.1%, sodium benzoate 0.1%, artificial flavor, color, Vitamin A palmitate, Vitamin D_2, Vitamin E (d-l-α tocopherol, ascorbyl palmitate). Contains: 3,525 IU Vitamin A, 660 IU Vitamin D and 18 IU Vitamin E per 100 g.
Label Claim - 52 % liguid sunflower oil, 33% polyunsaturated, 20% saturates.

Tubs:

Canola

West - Hydrogenated vegetable oil 80%, moisture not more than 16%, salt 2.5%, milk solids 1.4%, vegetable lecithin 0.2%, vegetable mono and di-glycerides 0.1%, sodium benzoate 0.1%, artificial flavor and color, Vitamin A palmitate (3525 IU per 100 g), Vitamin D_2 (600 IU Vitamin D per 100 g).

Corn

Fleischmann's - 3,525 IU Vitamin A, 600 IU Vitamin D per 100 g, Liquid corn oil 44%, hydrogenated corn oil 36%, moisture 16%, salt 2.4%, skim milk powder 1.4%, lecithin 0.2%, vegetable mono and di-glycerides 0.1%, sodium benzoate 0.1%, artificial flavor and color, Vitamin A palmitate, Vitamin D.
Label Claim - 40% polyunsaturates, 18% saturates, 55% liquid corn oil.

Soy

Blue Bonnet - 3,525 IU Vitamin A, 660 IU Vitamin D per 100 g, Liquid soybean oil 41%, hydrogenated soybean oil 39%, moisture 16%, salt 2.4%, skim milk powder (and may contain whey powder) 1.4%, lecithin 0.2%, vegetable mono and di-glycerides 0.1%, sodium benzoate 0.1%, artificial flavour and color, Vitamin A palmitate, Vitamin D.

Sunflower

Achieve - Sunflower oil 80% (liquid sunflower oil 54% hydrogenated sunflower oil 26%), salt 2%, skim milk powder 1.4%, sorbitan tristearate 0.2%, vegetable lecithin 0.1%, vegetable monoglycerides 0.1%, sodium benzoate 0.1%, artificial flavor, color, Vitamin A palmitate, Vitamin D_2, Vitamin E (d-ℓ-α tocopherol, ascorbyl palmitate). Contains: 3,525 IU Vitamin A, 660 IU Vitamin D and 20.1 IU Vitamin E per 100 g.
Label Claim - 68 % liquid sunflower oil, 44% polyunsaturates, 18% saturates.

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