Rapeseed Oil in a Two-Component Margarine Base Stock

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Abstract

A two-component margarine base stock with liquid oil as one component allowed for a lower *trans* fatty acid content and at the same time provided for a higher essential fatty acid level than a one-component base stock. Transesterification softened a two-component margarine base stock and resulted in a steeper solid fat index curve, but did allow for a lower *trans* fatty acid level in a margarine base stock. The high content of erucic acid in rapeseed oil did not change the physical properties of a margarine base stock and provided a good hardstock when this oil was hydrogenated. The use of a hydrogenated rapeseed oil ensured interchangeability of liquid oils in blends and rearranged blends, also seemed superior to soybean hardstocks in this respect.

Introduction

RAPESEED OIL WAS USED in margarine manufacture in Europe before World War II and, after the war, was introduced into Canada, Japan, and other countries. Many studies concerning the nutritional value (5) of rapeseed oil, its physical properties, stability, and processing have been carried out, but there is little published information available in regard to the specificity and interchangeability of this oil and its hardstocks when compared with other commercial vegetable oils and hardstocks for margarine blends (4,7,11,15,16,19,21,22,24,25,28). As rapeseed oil differs significantly in composition from other oils which are currently used in margarine production, a study was carried out on the advantages and disadvantages of the use of rapeseed oil and rapeseed hardstocks in margarine base stocks.

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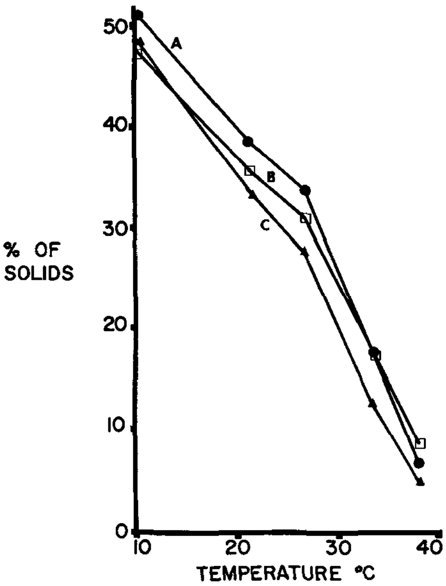


FIG. 1. Solid fat index of the hardstocks used in the laboratory-prepared blends: A—soybean selectively hydrogenated hardstock, B—rapeseed hardstock nonselectively hydrogenated, C—rapeseed hardstock selectively hydrogenated.

Methods, Materials, and Procedures

The iodine value (1), solid fat index (3), and consistency measured at 21.1C after 24 hours of tempering at 56.7C and after 48 consecutive hours at 21.1C was carried out according to AOCS procedure (2). The *trans* fatty acids content was determined according to the Swern (18) method with the aid of a Beckman IR-7 spectrophotometer. Absorption of natural fats with no *trans* fatty acids was estimated for the same conditions, and this correction was subtracted from the spectrophotometer readings. The results were reported in percentage of *trans* acids as compared with pure trielaidin.

Essential fatty acids (EFA) were estimated spectrophotometrically as *cis-cis* conjugated hydroperoxides after enzymatic oxidation (17). This method gave good reproducibility and good agreement between calculated and experimental data. The molar absorption factor suggested by McGee has been used to make our findings comparable with others (34).

All oils used in the laboratory-prepared blends were refined, bleached, hydrogenated, and deodorized under commercial processing conditions. The solid fat index (SFI) and chemical characteristics of the hardstocks in the laboratory-prepared blends are shown in Fig. 1 and Table I. Transesterification was conducted with −0.5% sodium methoxide catalyst under a vacuum at 55C for one hour. The catalyst was inactivated with 2% of water, and the soaps were removed by filtration through a Celite filter bed. Rearranged blends were vacuum-dried before and after catalyst treatment.

Results and Discussion

Commercial Margarines

The SFI curves of the American margarines were flatter than Polish and Canadian margarines (Fig. 2A, 2B). None of the margarines had a significant content of solids at 37.8C, and none of them had the convex type of SFI curves. Soft (cup) margarines had flatter SFI curves than stick-type margarines, which allowed for a spreadable consistency over a wide range of temperatures.

The iodine value ranged from 74–77 in all-hydrogenated rapeseed oil stocks for Canadian and Polish margarines to 115–125 in soft soybean and safflowerseed, two-component American margarine blends (Table II). The *trans* fatty acids content varied from 18–21% in American cup products to 47–55% in American and Polish all-hydrogenated stocks. Soft margarines and blends with nonhydrogenated oils showed lower *trans* fatty acids content when compared with all hydrogenated margarine bases.

The essential fatty acids content varied from 3–5%

TABLE I
Chemical Characteristics of Hardstocks Used in Laboratory-Prepared Blends

Code	Hardstock	IV	% *trans*	% EFA
A	Soybean selective	68	63	0
B	Rapeseed nonselective	65	48.5	1.0
C	Rapeseed selective	68	58	0
D	Soybean hard fat	6.5	2.5	0
E	Rapeseed hard fat	18	14	0

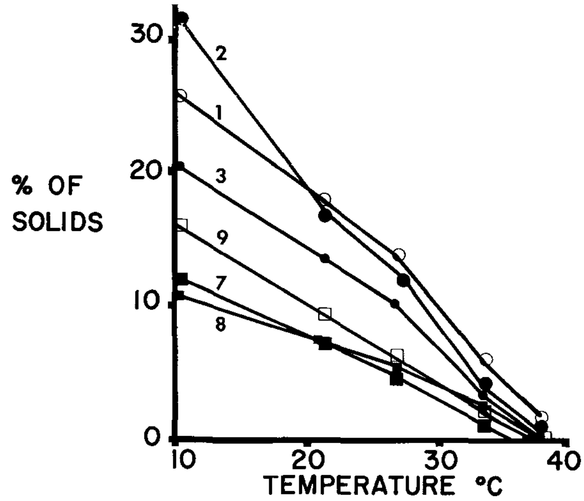


FIG. 2A. Solid fat index of commercial American margarines. Composition and chemical characteristics are shown in Table II.

in Canadian and Polish all-hydrogenated rapeseed oil margarine bases to 50–66% in soft American soybean and safflowerseed oil blends. Margarines prepared from hydrogenated stocks seemed to contain significantly less EFA than margarines prepared from blends with nonhydrogenated oils; stick margarines contained about one-half the EFA of cup margarines.

Laboratory-Prepared Blends

The American stick and cup margarines did not follow as closely the SFI curve of butter as the European margarines and provided a wider temperature range of plasticity and spreadability (Fig. 2C). A SFI curve which fitted the solid content of American commercial margarines was therefore used as a criterion for the laboratory-prepared blends. No negative deviation from the straight line (convex type of SFI curve) was allowed.

Liquid Rapeseed and Corn Oil Blends and Rearranged Blends with Soybean Hardstocks. Corn oil in blends gave a more suitable SFI curve than rapeseed oil (Fig. 3A). Corn oil blends showed less change in solids than rapeseed oil at a temperature range of 21–27.1C and a steeper SFI curve at a range of 27–38C, which ensured a lower solid content at

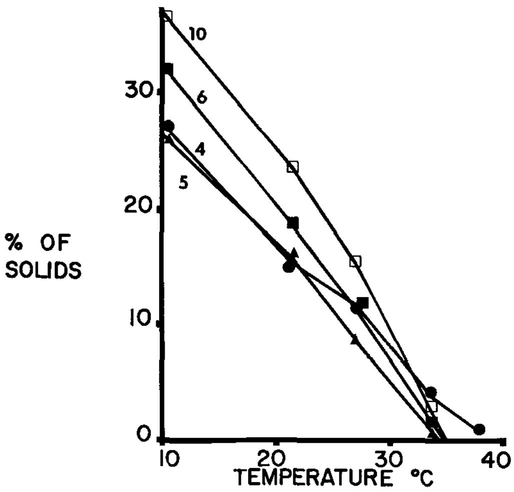


FIG. 2B. Solid fat index of commercial Polish and Canadian margarines. Composition and chemical characteristics are shown in Table II.

TABLE II

Chemical Data of Margarines Produced in the U.S.A., Poland, and Canada[a]

Margarine type	Stick			Stick	Stick		Cup			Baker
Country of production	U.S.A.			Canada	Poland		U.S.A.			Poland
Sample No.	1	2	3	4	5	6	7	8	9	10
Iodine value	95.7	82.9	94.8	77.2	96.3	74.0	114.5	125.1	97.7	83.0
% *trans*	40.5	46.9	34.4	41.5	43.1	41.1	20.5	18.1	37.1	54.8
% EFA	27.7	14.5	31.7	3.0	23.0	5.0	47.6	66.4	40.0	10.1

[a] Label declaration on the commercial margarine base stocks: 1. all hydrogenated cottonseed and soybean oil; 2. all hydrogenated corn oil; 3. hydrogenated soybean, liquid corn oil, hydrogenated cottonseed oil; 4. all-hydrogenated rapeseed two-component stock; 5. palm oil, peanut oil, hydrogenated vegetable oil; 6. no composition declared (probably all-hydrogenated rapeseed oil); 7. liquid soybean, hydrogenated soybean, and cottonseed oil; 8. liquid safflower oil; 9. partially hardened soybean liquid and hardened cottonseed oil; 10. all-hydrogenated vegetable stock (probably rapeseed oil). (Included in 8 is also hydrogenated soybean oil.)

37C. Soybean hardstock A which contained a high solid content at 37.8C (Fig. 1) was more suitable for a cup type of margarine, but both types (stick and cup) could be prepared from rapeseed or corn oil. Transesterification of the blends significantly softened the base stocks and yielded steeper SFI curves, which were more suitable for stick margarine bases (Fig. 3B). Rapeseed oil transesterified blends with soybean hardstock A allowed for a better SFI curve than corn oil. A cup transesterified base could not be obtained with hardstock A since, in the proper range of solids at refrigerator temperatures, it gave a steep and a convex type of SFI curve which made the product too soft at room temperatures.

The no-*trans* acid blends with completely hydrogenated soybean hardstock D gave a completely unsuitable SFI curve for any type of margarine, as shown in Fig. 3C. Transesterification of the no-*trans* fatty acids blends improved their physical properties but yielded an unsuitable convex type of SFI curve with considerable amounts of solids at 37C. A no-*trans* fatty acids corn oil rearranged blend, however, gave a good SFI for shortening. Thus rearrangement of liquid oil blends with completely hydrogenated hardstocks might provide semisolid fats (23,30) rich

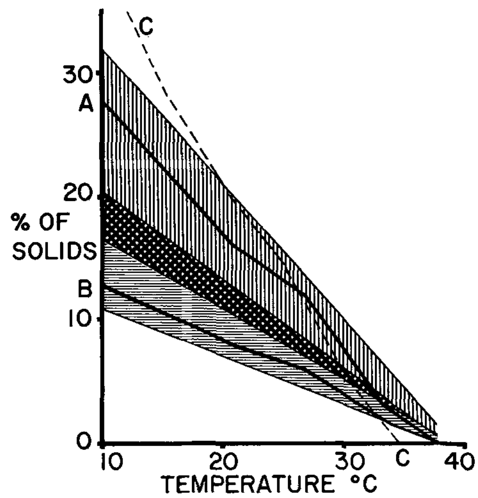
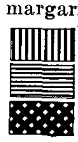


FIG. 2C. Solid fat index range for laboratory-prepared margarine blends:



area found in commercial stick margarines

area found in commercial cup margarines

area for harder cup margarines

A and B—typical SFI of American stick and cup margarines (33), C—SFI of butter (4).

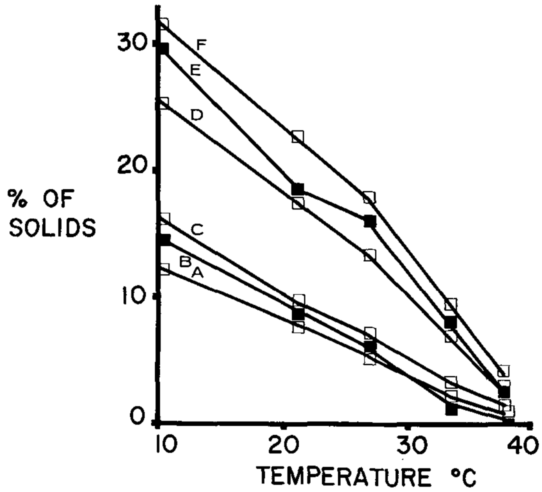


FIG. 3A. Solid fat index of laboratory-prepared blends with soybean hardstock A.

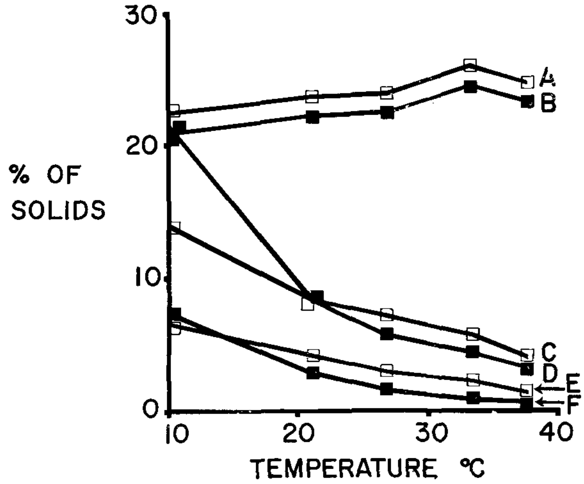


FIG. 3C. The no-*trans* acid blends and rearranged blends with soybean hardstock D:

□—corn oil
■—rapeseed oil

A,B—20% hardstock blended with A—corn oil, B—rapeseed oil; C,D—30% hardstock rearranged with C—corn oil, D—rapeseed oil; E,F—20% hardstock rearranged with E—corn oil, F—rapeseed oil.

in EFA and practically devoid of *trans* fatty acids. These fats, however, had physical properties which are unsuitable for margarine base stocks. Fractional crystallization may allow for adjustment of the SFI curve for good margarine bases. Several patents in this area have been recently issued, but there is little available information about commercial use of these techniques in margarine production (20,27,29,31). In other patents a high solid content at 37C was decreased by use of short-chain fatty triglycerides and by medium-chain oils in transesterified blends (6,9,20,24,26,27). These randomized blends contained short- and/or medium-chain saturated fatty acids which had lower melting-points and better intersolubility with other types of triglycerides (24).

Liquid Rapeseed Oil and Safflowerseed Oil Blends and Rearranged Blends with Rapeseed Hardstocks. The SFI curves of the blends prepared from nonselectively hydrogenated rapeseed hardstock B are shown in Fig. 4A. Both rapeseed and safflowerseed oil gave the same SFI in a blend; therefore they might be considered as completely interchangeable in this system. Hardstock B was suitable for composition of a soft type of margarine blend but created difficulties when a stick margarine blend was desired because of a high solid content at 37C. Selectively hydrogenated rapeseed hardstock C allowed for proper cup and stick margarine blends with both oils as shown in Fig. 4B.

Transesterification of rapeseed oil hardstock B and E blends resulted in changes similar to those described in soybean hardstock (12,13) (Fig. 4C, 4D). However complete interchangeability of the oils in the blends and the rearranged blends was possible when rapeseed oil hardstocks were used. To investigate further this desirable feature of rapeseed oil hardstocks, cup margarine blends with hardstock B and stick margarine blends with hardstock C were prepared. Five different liquid oils were used in blends with rapeseed, soybean, corn, cottonseed, and safflower-

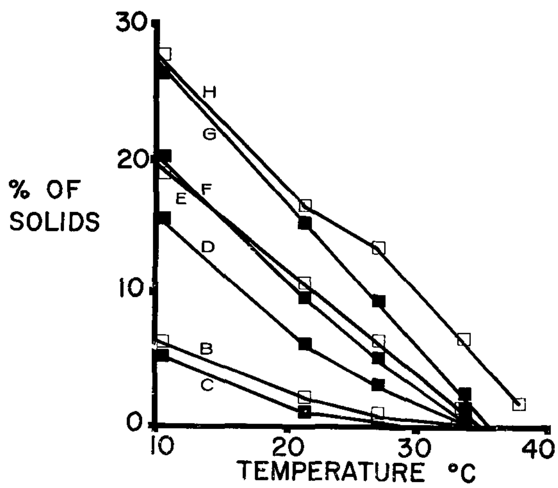


FIG. 3B. Solid fat index of laboratory-prepared, rearranged blends with soybean hardstock A:

■—corn oil blends
□—rapeseed oil blends

% of liquid oil in blends

Liquid oil	70	65	45	35	25
Rapeseed	A	C	D	F	G
Corn		B		E	H

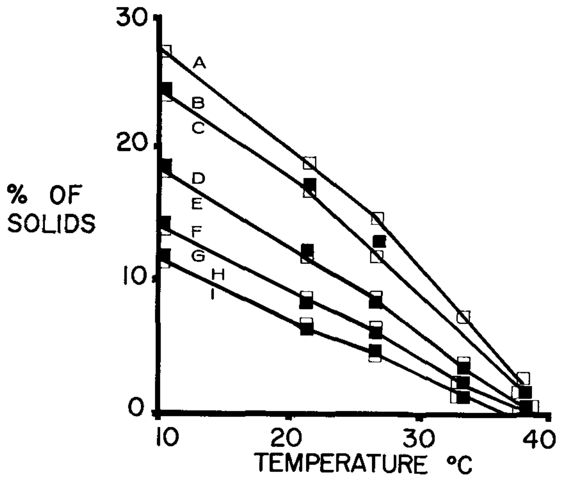


FIG. 4A,B,C,D. Liquid rapeseed and safflower oil blends or rearranged blends with rapeseed oil hardstocks B, C, E:

□—safflower oil blends
■—rapeseed oil blends

FIG. 4A. Simple blends with hardstock B: A—40% safflower oil, B,C—45% safflower or rapeseed oil, D,E—55% safflower or rapeseed oil, F,G—65% safflower or rapeseed oil, H,I—70% safflower or rapeseed oil.

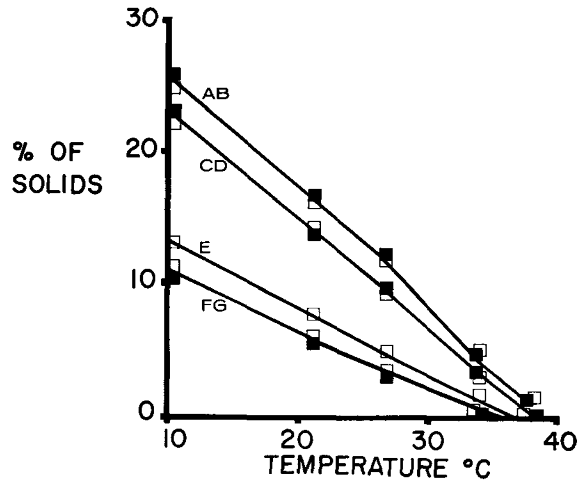


FIG. 4B. Simple blends with hardstock C: A,B—40% safflower or rapeseed oil, C,D—45% safflower or rapeseed oil, E—65% safflower oil, F,G—70% safflower or rapeseed oil.

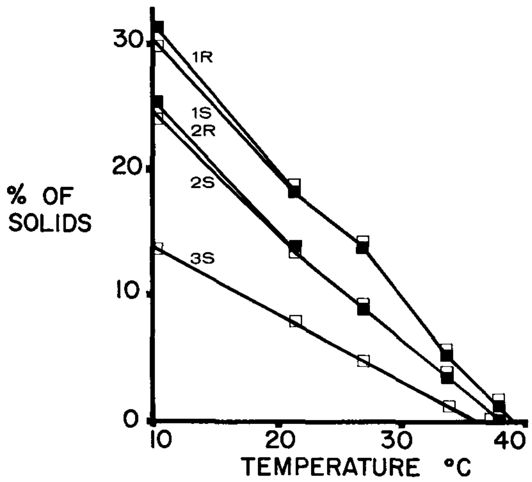


FIG. 4C. Rearranged blends with hardstock B: 1R,1S—20% rapeseed or safflower oil, 2R,2S—25% rapeseed or safflower oil, 3S—35% safflower oil.

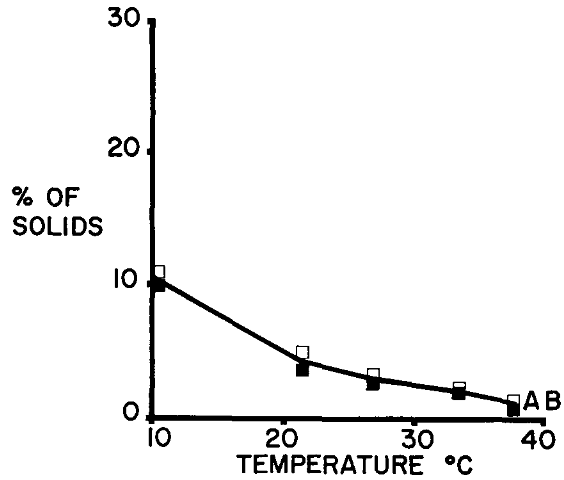


FIG. 4D. Low *trans* fatty acids rearranged blends with hardstock E: A,B—70% liquid safflower or rapeseed oil.

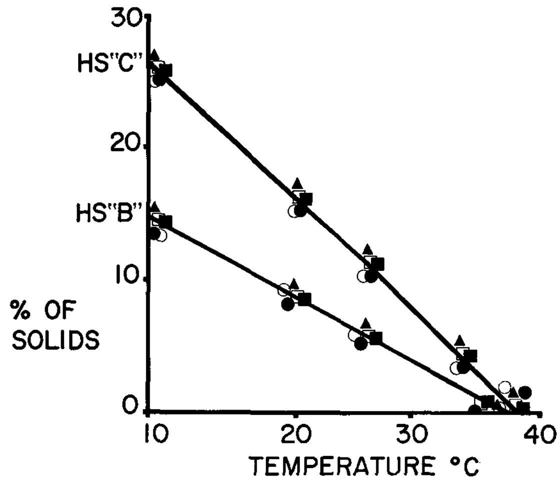


FIG. 5AB. Interchangeability of liquid oils in blends (Figure 5A) and rearranged blends (Figure 5B) with rapeseed oil hardstocks B, C:

□—cottonseed oil
●—corn oil
▲—rapeseed oil
○—safflowerseed oil
■—soybean oil

FIG. 5A. HS "C" line—SFI of the stick margarine blends composed with hardstock C and 40% liquid oils; HS "B" line—SFI of the cup margarine blends composed with hardstock B and 65% liquid oils.

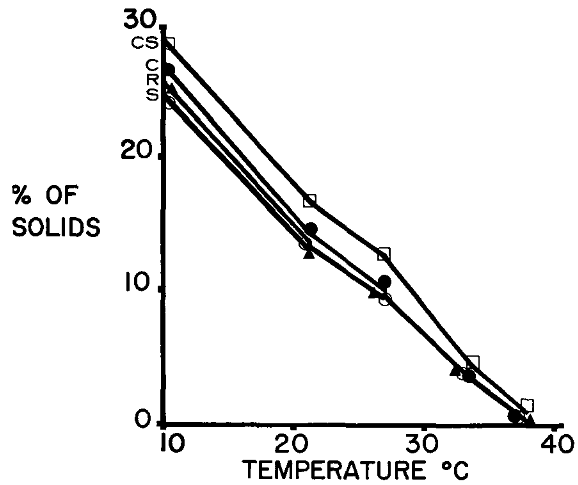


FIG. 5B. Stick margarine rearranged blends with hardstock B and 25% of liquid oils.

seed oil. Complete interchangeability of all oils in blends has been confirmed, as shown in Fig. 5A.

The same study was repeated on transesterified rapeseed oil hardstock B blends for a stick margarine base, and little difference was noted between the blends (Fig. 5B). The solid fat content at range of temperatures (10–37C) increased in the order of safflower, rapeseed, corn, cottonseed. The same order existed in saturated fatty acid content in the oils which were investigated. The interchangeability of the liquid oils in rearranged rapeseed hardstock blends was limited not by the degree of unsaturation or by the length of the chains of fatty acids but mainly by the saturated fatty acids content of the liquid oils. The difference in behavior of soybean and rapeseed oil hardstocks in blends, especially in rearranged blends, might be explained by the crystal structure. A polymorphic structure which has a strong effect on SFI and polymorphic changes can be studied and interpreted by the means of dilatometry (14,32). The C_{18} fatty acids in soybean oil triglycerides yield a β or β' crystal form when blended or rearranged with other C_{18} oils as with corn oil. But when soybean hardstock was blended or rearranged with C_{22}/C_{18} rapeseed oil, crystallization in the β form was decreased (14) in blends and completely inhibited in randomized blends (8,10).

TABLE III

Composition and Chemical Characteristics of Laboratory-Prepared Margarine Blends with Hardstocks A, B, C

Type of margarine		Comp. in % of hard stock	% of *trans*	% EFA in blends with liquid oils: Rapeseed	Corn	Safflowerseed
Blends	Cup	A BC 28—40	B AC 14.5—25.2	C A 14.4—17.3	B A 33.6—39.2	C A 46.2—53.9
	Stick	A BC 43—65	B AC 23.3—37.7	C A 8.4—13.7	C A 19.6—28.0	C A 26.9—40.0
Rearranged Blends	Cup	B 65—70	B 31.5—34.0	B 7.2— 8.9	....	B 23.1—27.0
	Stick	A B 68—80	B A 34.3—49.1	B A 4.8— 7.7	B A 12.3—19.6	B 15.4—19.2

Thus soybean hardstock gave slightly different shapes of SFI curves in blends and strong differences in randomized blends when C_{18} oil or other than C_{18} liquid oil was used. Rapeseed oil hardstock however contains enough C_{22} fatty acids to prevent crystallization in the β form, no matter what oil is used in blends or rearranged blends. The same crystal form gave the same SFI in the range 10–37C for any liquid vegetable oil blends. The saturated fatty acids content in liquid oil represented the only limitation of interchangeability in rearranged blends. A stable β' crystal in rapeseed hardstock margarine blends is desirable since it ensures a fine crystal structure, which prevents oil bleeding, gives firmer consistency and prevents polymorphic changes that develop graininess, stiffness, and other undesirable physical changes during storage (4,33).

Thus rapeseed oil hardstock is superior to soybean hardstock since it ensures interchangeability of liquid oils and gives a stable β' crystal form which is more suitable for margarine bases.

Composition and Chemical Characteristics of Laboratory-Prepared Margarine Blends. The iodine value, *trans* fatty acids, and essential fatty acids content were determined in the components of the blends. The values for blends were calculated from composition and occasionally confirmed by chemical analysis. Effect of transesterification on iodine value, *trans* and essential fatty acids content was investigated on hardstocks and liquid oils. A slight increase in *trans* acids level <0.5% and a slight decrease of EFA content <1.5% was observed after transesterification. These reproducible changes, however, were in the range of the error of applied methods and were not considered in calculation. No change in iodine value

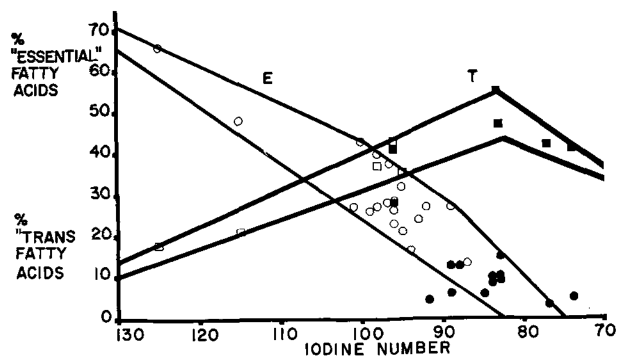


FIG. 6ABCD. The *trans* and essential fatty acids content in margarine base stocks.

FIG. 6A. Commercial margarines:
○—EFA content in blends with liquid oils
●—EFA content in all-hydrogenated bases
□—The *trans* fatty acids content in blends with liquid oils bases
■—The *trans* fatty acids content in all-hydrogenated bases

Data contain results published by Zmachinski et al. (34) as well as the authors' own experimental findings.

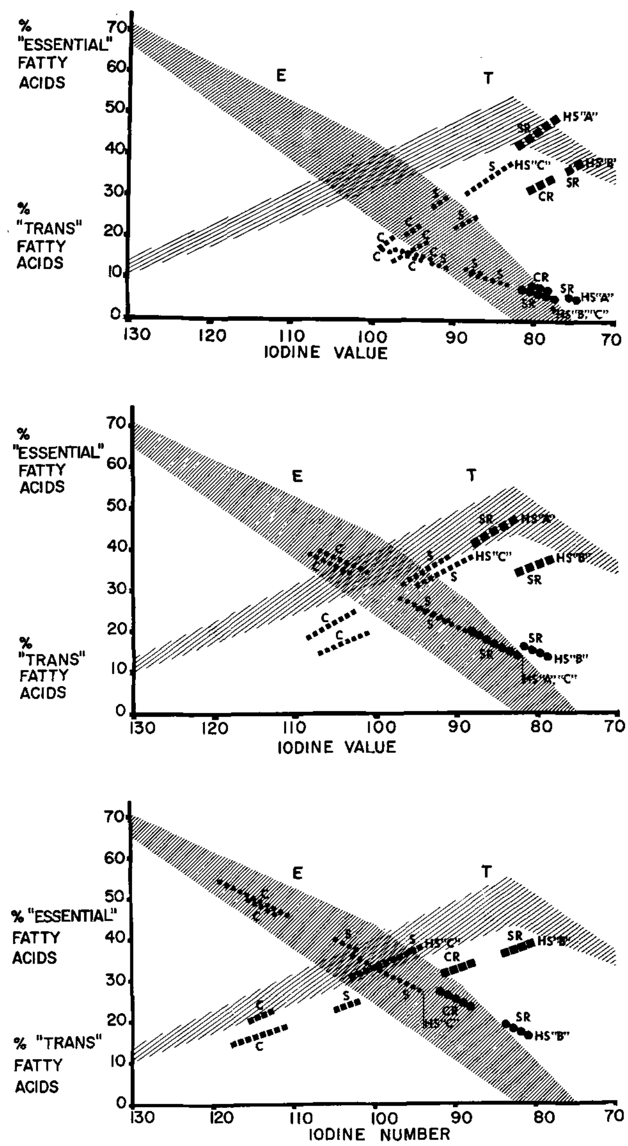


FIG. 6BCD. Laboratory-prepared margarine bases:
6B—with rapeseed oil; I.V. 111, EFA content 24%
6C—with corn oil; I.V. 126, EFA content 56%
6D—with safflowerseed oil; I.V. 142, EFA content 77%

E—EFA content area found in commercial margarines
T—The *trans* fatty acids area found in commercial margarines

HS "A"—blends with hardstock A, HS "B"—blends with hardstock B, HS "C"—blends with hardstock C.

C—simple cup margarine blend, S—simple stick margarine blend, CR—cup margarine rearranged blend, SR—stick margarine rearranged blend.

●—EFA content in rearranged blends
• —EFA content in blends
■—The *trans* fatty acids content in rearranged blends
▪ —The *trans* fatty acids content in blends.

was observed during transesterification. Transesterification treatment resulted in partially bleached corn, cottonseed, and safflowerseed oil and slightly darkened rapeseed oil margarine bases. All rearranged blends developed a slight pleasant nutty flavor.

Effect of the Type of Margarine. Stick margarine contained almost twice as much hardstock as cup margarine blends. This difference in composition increased *trans* and decreased essential acids content, respectively, as shown in Table III and Fig. 6ABCD. In addition, cup margarine can be prepared with harder or nonselectively hydrogenated hardstock which has a lower fatty *trans* acids content, and for that reason the *trans* acid level in soft margarine might be even lower. The same factor might reflect also on EFA content in soft margarine blends. Firmer hardstock would allow for more liquid oil in the blend and for an increase of EFA level in soft margarine.

Effect of Rearrangement. Since rearrangement softens margarine blends, about twice as much of the hardstock has to be used to ensure proper SFI for both types of margarine. A higher content of hardstock doubles *trans* acid content and decreases EFA level respectively. Thus transesterification treatment is not desirable from the essential and *trans* fatty acids content standpoint, but other reasons, such as better oxidative stability, steeper SFI, or stable β' crystal form, might justify this treatment in commercial processing.

Effect of the Hardstock. The solids content in margarine blends is determined by SFI of the hardstocks. Differences in selectivity and degree of hydrogenation strongly affect the composition of the blends. The lowest *trans* acid content was obtained in blends with nonselectively hydrogenated rapeseed oil hardstock B and the highest with selectively hydrogenated rapeseed and soybean hardstocks A and C. Soybean hardstock A, because of its high solids content (Table III), allowed for the higher EFA content in prepared blends. Harder and less selectively hydrogenated hardstock allows for lower *trans* and higher EFA content. This observation, however, applies only to a narrow range of proper SFI for blends composed in this system. A proper stick margarine blend cannot be obtained from hard or nonselectively hydrogenated oils. The same limit, but at a higher range of hydrogenation and lower selectivity, can also be applied to cup margarine bases.

Effect of Liquid Oil. The two-component margarine blends prepared in our laboratory with liquid oil had a lower *trans* acids content than commercially produced margarines (Fig. 6ABCD). However, when blends were rearranged in this system, the *trans* acid level increased. Essential fatty acid content was determined by the EFA level of the liquid oil used in blends; rapeseed oil gave the lowest values, which were in the range of all-hydrogenated bases of commercial margarines. The EFA content of corn oil blends were in the middle of commercial margarine values, and safflowerseed oil blends gave the upper middle range of EFA content in commercial margarines. As liquid oils are basically interchangeable in blends, the richer in EFA oil the better; but oils containing linolenic acid are limited by stability and reversion problems.

ACKNOWLEDGMENT

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REFERENCES

1. AOCS Official Method, Revised 1956, No. Ka 9–51.
2. AOCS Tentative Method, No. Cc 16–60.
3. AOCS Tentative Method, Revised 1960, No. Cd 10–57.
4. Andersen, A. J. C., and P. N. Williams, "Margarine," Pergamon Press, New York, 1965, p. 53.
5. Blattina, J., and J. Manouskowa, Veda Vyzkum Prumyslu Potravinarskem. *12,* 251–274 (1963).
6. Melnick, D., and C. M. Gooding (Corn Products Company), U.S. 2,921,855 (1960).
7. Czaplicki, J., Prace Inst. Lab. Badawczych Przemyslu Spozywczego *9,* 113–131 (1963).
8. DeWitte, N. (Swift and Company), U.S. 2,855,311 (1960).
9. Babayan, V. K. (Drew Chemical Corporation), Ger. 1,215,679 (1966).
10. Hannewijk, J., Chem. Weekblad *60,* 309–316 (1964).
11. Jakubowski, A., Prace Inst. Lab. Badawczych Przemyslu Spozywczego *4,* 113–131 (1963).
12. Kaczanowski, C. Z., and A. Jakubowski, Tluszce i Srodki Piorace 7(2), 65–70 (1963).
13. Ibid., *8*(9), 189–194 (1964).
14. Kozin, N. I., and E. N. Makarenko, Tr. Mosk. Inst. Nar. Khoz. *24,* 56–62 (1963).
15. Krolikowski, W., and H. Niewiadomski, Prace Glownego Inst. Przemyslu Rolnego Spozywczego *3,* 23–24 (1953).
16. Linteris, L., and S. W. Thompson, JAOCS *35,* 28–32 (1958).
17. MacGee, J., Analyt. Chem. *31,* 298–302 (1959).
18. Mechlenbacher, V. C., "The Analysis of Fats and Oils," Garrard Press, Champaign, Ill., 1960, p. 533.
19. Nakazawa, K., S. Mitsunaga and K. Tada, Chem. Abstracts *51,* 12511 (1957).
20. Pokorny, E. M., and A. Makhanicheck, Chem. Abstracts *53,* 3737 (1959).
21. Procter and Gamble Company, Neth. 6,411,052 (1965).
22. Procter and Gamble Company, U.S. 3,298,837 (1967).
23. Walker, A. P., and D. S. Lindsay (Procter and Gamble Ltd.), Ger. 1,203,587 (1965).
24. Litchfield, C. C., and C. F. Bruce (Procter and Gamble Company of Canada Ltd.), Can. 7;3,5;2 (1965).
25. Rutkowski, A., and J. Dunaj, Tluszce i Srodki Piorace *4,* 197–205 (1960).
26. Taufel, K., M. Achtzehn and C. Franzke, Chem. Abstracts *52,* 17757 (1958).
27. Devlin, J. J., and A. P. Walker (Thomas Hedley and Company Ltd.), Brit. 832,377 (1960).
28. Tremazi, S. A., N. V. Lovegren and R. O. Feuge, JAOCS *42,* 78–81 (1965).
29. Oakley, H. B., and T. J. Guffick (Unilever Ltd.) Brit. 1,017,091 (1966).
30. Gander, K. F., J. Hannewijk and A. J. Haighton (Unilever, N. V.), Belg. 670,371 (1966).
31. Unilever, N. V., Belg. 633,053 (1963).
32. Vergelsov, V. M., A. P. Belousov, and Y. P. Adrianov, Izy. Vys. Uchebn. Zav. Pishch. Tekhnol. *5,* 50–55 (1965).
33. Wiedermann, L. H., AOCS Short Course, East Lansing, Mich. (1966); abstract, JAOCS *43,* 308A (1966).
34. Zmachinski, Helen, A. Waltking and J. D. Miller, JAOCS *43,* 425–428 (1966).

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