SOLIDIFICATION OF VARIOUS WATER-IN-MILK FAT EMULSIONS AND THEIR TASTE EVALUATIONS

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TABLE OF CONTENTS

	Page
INTRODUCTION	1
REVIEW OF LITERATURE	3
EXPERIMENTAL METHODS	7
RESULTS AND DISCUSSION	12
SUMMARY AND CONCLUSION	17
LITERATURE CITED	18
APPENDIX	20

LIST OF TABLES

Table — Page

I. Emulsifier Combinations and Concentrations Used to Prepare Spreads With 40% Milk Fat. . . 22

II. Example of Score Card Used by Individual Taste Panel Members. 23

III. Summary of Scores for a Group of Four Samples. . 24

IV. Taste Preferences of Fourteen Judges for Margarine, Butter or Low-fat Spreads Using a Paired Comparison Technique 25

V. Total Scores of Eight Judges for Margarine, Butter and Low-fat Spreads When Compared Within Each Group. 26

LIST OF FIGURES

Figure — Page

1. Laboratory Butter Churning Apparatus Consisting of Glass Churn, Plastic Dasher and Electric Motor of Variable Speed. 21

INTRODUCTION

The per capita butter consumption in the United States declined from 17.0 lb. in 1940 to about 7.5 lb. in 1960 (2). With increased milk fat production and a decreased market, a serious economic problem has been presented to the dairy industry. One major reason for the reduction in butter consumption has been the high price of butter in comparison to other edible fats. The price of margarine, one of the principal competitors for the butter market, has usually been about half that of butter. In the past, the fats in margarine have been worth 5 to 25 cents per pound, whereas milk fat has cost 50-65 cents per pound.

Looking at the present butter situation from an economic viewpoint, it appears that butter cannot immediately regain all the popularity it once enjoyed. However, if the price of this product were reduced to a competitive level, it might be possible for butter to regain at least part of the lost market. Since prices at present are regulated by government policy, it would not be possible to substantially reduce the price of milk fat. However, if a "butterlike" product could be produced which contained less than the normal amount of milk fat (80%) it then might be possible to price this item competitively.

Others from this laboratory have produced and evaluated low-fat spreads which contained a minimum of 30% milk fat. These spreads contained added cholesterol which was used as an emulsifier. However, blood cholesterol has been considered by some to be a factor in the development of heart disease. Thus it was proposed to use certain other emulsifiers to make low-fat spreads.

The objectives of this research were: (a) to investigate the properties of emulsifiers and find those types which could be used to make low-fat spreads, and (b) to study the taste of these spreads in comparison to normal butter and to margarine.

REVIEW OF LITERATURE

Becher (3) defined an emulsion as a dispersion of one phase (the disperse) in another (the continuous); the two phases being mutually immiscible. Various types of emulsions have been made, these included: liquid in liquid, liquid in solid, solid in liquid and solid in solid. Emulsions also have been classified either as water-in-oil types (w/o) or as oil-in-water types (o/w). Butter has been shown to be a w/o emulsion of a liquid (water) dispersed in a solid (crystalline milk fat).

General discussions on the theory of emulsions (4) indicated that a w/o emulsion containing at least 74% of the continuous phase could be produced without the addition of emulsifying agents. If emulsifying agents were used, it was possible to form a w/o emulsion, in which the continuous phase constituted as little as 26% of the total weight.

This had not been done with edible fats. However, general reports on margarine manufacture (18) indicated that the amount of crystalline fat necessary for the product to maintain its shape was 10 to 32%. Therefore, it was logical to assume that w/o type emulsions containing 40 to 74% milk fat could be produced if proper emulsifiers could be found.

According to Becher (4) an emulsion may be formed by "brute force" or by "persuasion." This author went on to say that better emulsions could be made by the "persuasion" method. However, it often was more practical to make emulsions by the "brute force" method, i. e., vigorous mixing. When the persuasion method was used, the best way to incorporate an emulsifying agent was to dissolve it in the oil, the emulsion then could be formed either by: (a) adding the fat mixture to water in which case an o/w emulsion was formed spontaneously, or (b) by adding water to the fat mixture, in which case a w/o emulsion was formed.

According to Becher (3, 4) emulsion stability could be increased by: (a) lower interfacial tension; (b) higher viscosity; (c) smaller particle size (of the disperse phase); (d) the presence of an interfacial film, or (e) the presence of electrical charges on the droplets of the disperse phase. Bennet (5) reported that emulsion instability was caused by: (a) an improper ratio of the oil and water phases; (b) an incorrect amount or type of emulsifier; (c) rapid addition of oil to the water (which causes ineffective dispersion), or (d) impurities in either of the phases.

Emulsifiers, with HLB[a] numbers ranging from 2 to 18, were commercially available. Several publications (1, 3, 17) indicated that emulsifiers with HLB numbers of 4 to 6 were most effective in producing w/o emulsions. These publications also indicated that blends of chemically similar

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[a]The HLB number of an emulsifier is an expression of its Hydrophile-Lipophile Balance, i. e., the ratio of the size and strength of the hydrophilic (water-loving) to the lipophilic (oil-loving) groups of the emulsifier.

emulsifiers were very effective in making stable emulsions, i. e., stearate plus stearate, oleate plus oleate, etc.

Several low-fat spreads which were o/w emulsions have been developed. A dairy spread named "Dyne" was investigated at the University of Wisconsin (19). This spread contained 28% milk fat, 19 to 20% solids-not-fat and 1.3% NaCl. Dyne was sold for 23 cents per half-pint milk bottle. Other low-fat spreads of the o/w type containing 26 - 36% milk fat also have been developed (12). Some of these spreads also contained added preservatives, and milk solids from cottage cheese curd or condensed milk. Of these, the spread containing 36% milk fat and condensed milk was thought to be the most promising. The price of these spreads was estimated to range from 18 to 41 cents per pound. Whipped butter products (air whipped into butter) containing 50 to 80% milk fat were investigated at the Illinois Agricultural Experiment Station (13).

Recent work from this laboratory (11) resulted in the production of w/o type spreads containing 40 or 60% milk fat, 2% NaCl, 0.0-0.4% flavor and water. The spread which contained 40% fat also included 2% cholesterol as an emulsifier. The authors (11) found that the spread containing 60% milk fat could be prepared without the addition of an emulsifying agent. Taste panel data indicated few, if any, taste preferences when the spreads containing 40 or 60% milk fat were compared to control samples (butter containing 80% milk fat) and margarine.

The usefulness and precision of taste panel data will depend upon the design used when the food products are presented to it. In recent years several investigators have compared various taste panel designs. Three of these designs, paired, duo-trio and triangular, were studied by Gridgeman (8) using three materials of widely different flavors. He reported that paired and triangular tests were equally sensitive and both were more sensitive than the duo-trio test. Byer and Abrams (7), Lockhart (10) and Sawyer et al. (16) showed that the paired test was more effective than the triangular test, for measuring quality, or consumer preferences. This was especially true in a long tasting session (16).

A study by Sather and Calvin (15) showed that for mild products, up to 20 samples could be tasted in one test period with no decrease in the judges ability to discriminate among samples.

According to John (9) a mass taste panel which was a true cross-section of the population could be set up to provide reliable guidance concerning the acceptability of a new product. In such a panel, however, there was a possibility of obtaining a high percentage of "no preference" votes.

EXPERIMENTAL METHODS

Milk fat for this study was obtained from a single lot of unsalted 92 score butter. This butter was melted and the fat decanted and filtered through a single gauzed, fibre-bonded, filter.[1] The fat was then stored at -15°C until needed.

Ten different emulsifiers were obtained from commercial sources to use in this work. The various combinations of these emulsifiers which were used and their commercial sources are listed in Table I. Three of these, Span 65,[2] Span 85[2] and Glycerol mono-oleate[3] were used in the low-fat spreads which were evaluated by the taste panel. Three fatty acids, stearic,[4] oleic[5] and lauric[4] also were used in this work in combination with stearate, oleate and laurate-type emulsifiers. Oleic acid increased the emulsion stability when used with Glycerol mono-oleate.

Low-fat spreads containing 40% milk fat, 2% NaCl, emulsifier and water were prepared in this study. These 40% spreads were not evaluated by the taste panel because the large amounts of emulsifiers which were necessary usually produced intense off-tastes in the spreads. Spreads containing

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[1]Johnson and Johnson, Chicago 38, Ill.
[2]Atlas Powder Co., Wilmington, Delaware.
[3]Glycol Chemicals, Williamsprots, Pa.
[4]Eastman Organic Chemicals, Rochester 3, New York.
[5]Fisher Scientific Company, St. Louis, Missouri

50% milk fat, 2% NaCl emulsifier and water then were prepared and evaluated by a taste panel. Three emulsifiers, Span 65, Span 85 and Glycerol mono-oleate plus oleic acid (GMO) were used in these 50% spreads at concentrations of 1.0%, 1.8% and 1.0 ∕ 0.25% respectively.

The spreads were crystallized in a small glass "churn" (Fig. 1) which was especially designed for this experimental work. The cylinder of this churn was 8.5 inches high and 3.7 inches in diameter with a usable capacity of 330 ml. The dasher was 3.45 inches in diameter and was driven by an electric motor specially wired to direct current. The speed of this motor was constant regardless of the viscosity of the butter during crystallization.

Four different brands of margarine were tasted in the laboratory by three trained judges. From these, one brand was chosen because of its superior taste to be used for taste panel evaluations. This margarine contained 79.4% fat,[6] 2% NaCl, 16.4% water, and 2.2% curd.

When crystallizing these spreads into butterlike products, the fat and emulsifier were mixed together, then heated at 80 to 90°C for 30 to 40 minutes to dissolve the emulsifier. In a separate container, NaCl was dissolved in the water and this mixture also was heated at 80 to 90°C for 30 to 40 minutes. After heating, the two mixtures were combined in a

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[6]The percentage of fat in the margarine was determined by Kohman analysis. The package indicated that the fat was 100% corn oil, partially hydrogenated.

blender[7] for 30 to 60 seconds. During this time a w/o emulsion usually was formed which remained stable for 4 to 5 minutes. This emulsion was placed immediately into the glass churn (Figure 1) and mixed at a speed of 200 rpm for two minutes. Then the churn was set into an ice-water bath at 4-7°C and the dasher was driven at 300 rpm for 2.5 to 4.0 minutes during which time the milk fat crystallized. The finished spread was then molded into quarter-pound aluminum molds whose inside dimensions were 1.25 x 1.25 x 4.75 inches. These molds had been previously lined with "Handi-wrap."[8] The quarter-pound of spread was given an outer wrap of aluminum foil, and then stored at -15°C for later taste panel evaluation.

Preliminary screening of the spreads was done in the laboratory by an informal panel of three trained judges. This informal panel screened out those samples with obvious undesirable tastes, saving only the best samples for the formal taste panel. The formal taste panel consisted of 14 female judges who were selected from the staff and students of the Department of Food, Nutrition and Institution Administration (FNIA) at Oklahoma State University. Of these 14 judges, two were colored and 12 were white; one was a dietician, two were teachers and 11 were students; four were married and 10 were single. Seven of the judges were 20 to 30 years of age, three were 30 to 40 years of age and four were 50 to 60 years of age.

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[7]Coronet Blender, Model B-6. Iowa Manufacturing Co., Manchester, Conn.

[8]A thin plastic wrap manufactured by the Dow Chemical Co.

The judges were aware of the purposes of the research but at no time during the study were they aware of the descriptions of individual samples. The taste panel's samples were taken from the -15°C storage 72 hours prior to tasting and stored at 7 to 10°C until used. The samples were judged at tables which were subdivided into individual booths that prevented each judge from seeing the samples of others. Salt-free soda crackers were used between samples to eliminate the taste of previous samples.

Taste panel evaluations were conducted once a week from September through December 1962, during which time ten groups of samples were evaluated. The first nine groups, each contained four samples; one was a control sample of butter which contained 80% milk fat, another was margarine which contained 79.4% fat. The other two samples were low-fat spreads which contained 50% milk fat. The tenth group contained four samples of low-fat spread.

When sent from the Dairy Department to FNIA, the four samples were identified as A, B, C and D in a random order. The taste panel evaluated these samples in pairs. To set up this paired-comparison the four samples were divided into the maximum number of pairs, e.g., AB, AC, AD, BC, BD and CD. The two samples in each of these pairs were randomly coded either as X or Y. The scores given by each judge were recorded as shown in Table III.

An example of one judge's samples and the coding of these is shown in Table II. For each pair of samples, the judges

were asked to give a score of "1" to the sample they preferred and a score of "2" to the other one. The judges were asked to evaluate these samples on the basis of taste alone. Color, NaCl and water content (factors which might have affected taste) were controlled and approximately the same in all samples. The samples were all soft enough so that their spreadability was not objectionable.

The taste preference data were pooled and analyzed statistically to test for differences, using the two-tailed test for organoleptic comparisons as described by Roessler, Baker and Amerine (14). The data of each group also were summarized to indicate the preferences within each group. These data were analysed to statistically test for differences among samples in a group using the rank analysis technique of Bradley (6). For this analysis, six judges who were sometimes late when tasting the samples were omitted and the data of the other eight judges were used.

RESULTS AND DISCUSSION

The ten emulsifiers were used individually, in combinations with each other and, in some cases, in combination with certain fatty acids. A total of 25 emulsifiers and combinations was used. These emulsifier mixtures have been listed in Table I together with the combinations used and the minimum concentrations necessary to produce stable emulsions.

Most of the HLB numbers of the emulsifier mixtures ranged from 0 to 9 but HLB numbers ranging from 2 to 5 were found to be the most effective in producing stable w/o emulsions. The chemical properties of the emulsifiers also influenced emulsion stability, for example a stable w/o emulsion could not be formed using Span 60 (sorbitan monostearate) although the HLB number of this emulsifier was 4.7. Mono-oleate, trioleate and tristearate emulsifier types were usually effective in the formation of stable w/o emulsions.

The data concerning taste panel preferences are shown in Table IV. These data were grouped as: comparisons between the control samples (80% milk fat) and all other spreads, comparisons between margarine and the low-fat spreads, and comparisons among the low-fat samples.

The taste panel members had only two choices when judging these samples. One sample of a pair had to be chosen as

"the best" and given a score of "1." The other sample of the pair, by comparison, then had to be "the worst" and given a score of "2." Thus, the usual statistical techniques of estimating significant differences in relation to the variability of the data had little meaning when applied to these raw taste panel data which consisted of only two numbers. However, statistical analysis could be applied to the totals of pooled data.

Taste panel data have been pooled or combined in a number of different ways. Each combination, however, involved certain assumptions about the data. Statisticians have not agreed about the validity of these assumptions and thus they have not agreed about the best method of analyzing taste panel data. Some workers have pooled the data of different judges over time and analyzed it by pairs. In this case statistical estimates were based upon the theory of binomial distribution. Roessler, Baker and Amerine (14) have published tables, based on this theory, that indicated the number of judges preferring one sample which was necessary to establish a significant difference between that sample and the other of the pair.

When these tables were used a statistically significant preference ($P < .05$) for the control samples over the margarine was indicated (Table IV, see footnotes e and f). The control samples also were preferred over the low-fat spreads ($P < .05$). There were no significant differences ($P > .05$) among the panel's preferences for margarine

samples and the low-fat spreads containing Span 65 or GMO. However, margarine was preferred ($P < .05$) over the low-fat spread containing Span 85. No statistically significant preferences ($P < .05$) were evident when the low-fat spreads were compared to each other.

In general then, the control samples were preferred to margarine and to the low-fat spreads but, there were no preferences evident when the panel compared the low-fat spreads containing Span 65 or GMO to margarine.

Bradley (6) was not willing to assume that judgements made at different times were similar, and thus did not pool taste panel data over time. Instead he developed tables, based on the binomial distribution, which could be used to analyze the differences among four samples presented to a taste panel at the same time. This study was designed so Bradley's tables also could be used to analyze the data.

To do this the score of each sample in each group was totaled over all judges (as shown in Table V). Bradley's tables indicated that samples in groups 3, 6 and 9 were statistically different; that is at least two of the four samples were different ($P < .05$). When these preferences were summarized it appeared that much of the time the panel had no preferences for any of the four samples presented to it. When preferences were expressed the controls were preferred to the margarine samples which in turn were preferred over the low-fat spreads.

Bradley's tables were complete only for eight treatments (judges) when four samples were used. Thus the data of only

eight judges could be used for these analyses, whereas the information obtained from all 14 judges had been used when analyzing the data with the tables of Roessler, Baker and Amerine (14). For this reason the author considered that the analysis using the tables of Roessler, Baker and Amerine was more nearly a true representation of the data.

In some cases there were variations in the preferences of individual judges. These differences were fairly constant from one group of samples to the next, i. e., one judge always preferred the control samples, another always chose margarine over Span 65, etc. To determine if these variations could be related to measurable characteristics of the judges, the data were sorted according to the age, color, occupation and marital status of the panel members. A survey of the data after sorting, however, indicated no apparent relation between judges' preferences and age, color, occupation or marital status. One judge (No. 45) who was a white, married student and in the 20 to 30 year age group showed little or no preference for any of the samples, apparently always making her choices in a random manner. The reason for this judge's behavior was not understood but there was no reason to disregard her data. Much of the apparent variability observed between judges and between groups of samples could have been explained on the basis of normal random variations. There was no evidence that the time involved in storing samples until the taste panel evaluated them affected their taste; in some cases this storage time was 10 weeks at -15°C.

There was no question but that real differences existed among the taste of most of these samples since the three trained judges could identify coded samples in the laboratory with great regularity. The only questions to be answered were whether these differences were important to a group of women who were not trained judges. These women had the ability to discriminate between samples as evidenced by the number of statistically significant differences between pairs of samples. Thus, in cases where the panel did not discriminate between samples one can conclude that the differences in these cases were not great enough to be important to the group.

SUMMARY AND CONCLUSION

The objectives of this research were: (a) to find those types of emulsifiers which could be used to make low-fat spreads, and (b) to study the taste of these spreads in comparison to butter and margarine. Emulsifiers with HLB numbers ranging from 2 to 5 were effective in increasing the stability of w/o emulsions containing 40 or 50% milk fat, 2% NaCl and water.

Three emulsifiers, Span 65, Span 85, and a mixture of Glycerol mono-oleate plus oleic acid were chosen to make spreads containing 50% milk fat, 2% NaCl, and water, which the taste panel later evaluated. The panel consisting of 14 female judges, evaluated these spreads in comparison to control samples containing 80% milk fat and to a sample of margarine containing 79.4% fat.

When the taste panel data were pooled over judges and time statistical analysis indicated that the control samples were preferred ($P < .05$) over margarine and all the low-fat spreads. However, there was no statistically significant preference ($P > .05$) between the taste of the margarine sample and that of the 50% spreads containing Span 65 or GMO as emulsifiers. The margarine sample was preferred ($P < .05$) over the spread containing Span 85 as an emulsifier.

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A P P E N D I X

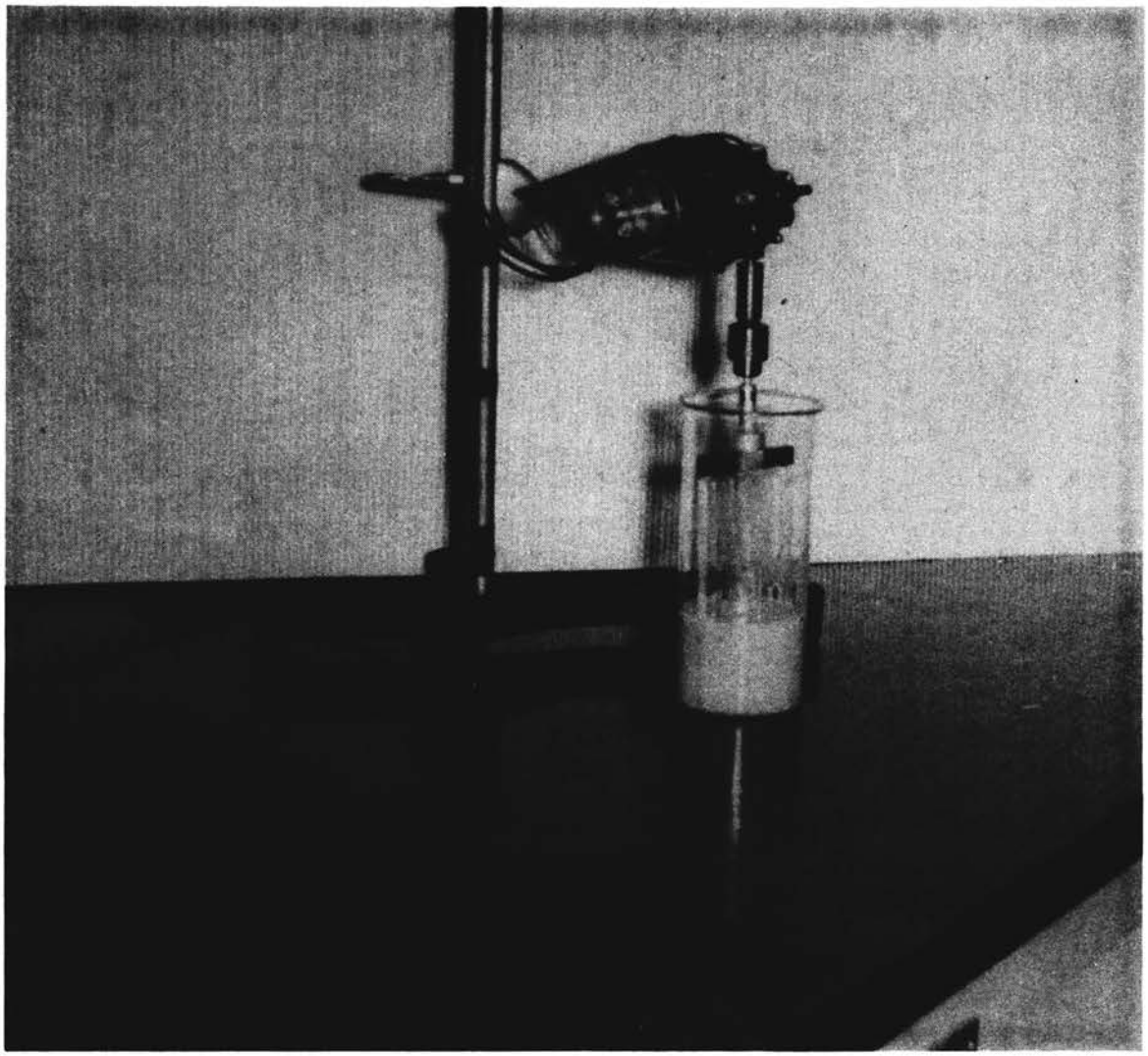

Figure 1. Laboratory butter churning apparatus consisting of glass churn, plastic dasher and electric motor of variable speed.

TABLE I

EMULSIFIER COMBINATIONS AND CONCENTRATIONS USED TO PREPARE SPREADS WITH 40% MILK FAT

Individual Emulsifiers	Concentration attempted (%)	Concentration minimum for a stable emulsion (%)
Span 85 (Sorbitan trioleate)[a]	0 - 10	5
Span 80 (Sorbitan mono-oleate)[a]	0 - 10	6
Span 65 (Sorbitan tristearate)[a]	0 - 10	1.8
Span 60 (Sorbitan monostearate)	0 - 10	10
Span 20 (Sorbitan monolaurate)	0 - 10	10
Glycomul (Sorbitan monostearate)[b]	0 - 12	11
Aldo 33 (Mono and diglycerides of edible fat-forming fatty acids)[b]	0 - 8	5
Glycerol mono-oleate[b]	0 - 8	4
Propylene glycol mono Stearate 64[b]	0 - 10	10
Atmul 124 (Mono and diglycerides from the glycerolysis of edible fats or oils)[a]	0 - 10	8
Combinations		
Span 85 / Span 80	0 - 7	6
Span 85 / Glycerol mono-oleate	0 - 3	-[c]
Span 80 / Glycerol mono-oleate	0 - 4	0.5 / 3.5
Span 65 / Span 60	0 - 6	-[c]
Span 65 / Glycomuls	0 - 3	-[c]
Span 65 / Propylene glycol monostearate	0 - 3	-[c]
Span 65 / Span 85	0 - 2	-[c]
Span 65 / Span 80	0 - 2	-[c]
Span 60 / Span 85	0 - 9	8
Span 60 / Atmul 124	0 - 10	-[c]
Span 60 / Span 80	0 - 5	-[c]
Glycomul / Glycerol mono-oleate	0 - 4	-[c]
Glycomul / Propylene glycol monostearate	0 - 8	-[c]
Propylene glycol monostearate / Glycerol mono-oleate	0 - 4	-[c]
Span 20 / Span 85	0 - 3	-[c]

[a]Atlas Powder Co., Wilmington, Delaware.
[b]Glycol Chemicals, Williamsport, Pa.
[c]Did not form a stable emulsion at any concentration used.

TABLE II

EXAMPLE OF SCORE CARD USED BY INDIVIDUAL TASTE PANEL MEMBERS

Judge number: 29 October 2, 1962

Sample Scores

Pair	X	Y
1	2	1
2	1	2
3	2	1
4	1	2
5	1	2
6	1	2

Directions: Rank each pair of samples on the basis of taste only. Score a "1" for the sample of each pair (X or Y) that you prefer and "2" for the other sample.

TABLE III

SUMMARY OF SCORES FOR A GROUP OF FOUR SAMPLES

Judge number: 29 October 2, 1962

Pair	Code X	Code Y	Sample Score A	Sample Score B	Sample Score C	Sample Score D
1	C	A	1		2	
2	B	A	2	1		
3	C	D			2	1
4	D	B		2		1
5	B	C		1	2	
6	D	A	2			1

TABLE IV

TASTE PREFERENCES OF FOURTEEN JUDGES FOR MARGARINE,[a] BUTTER[b] AND LOW-FAT SPREADS[c] USING PAIRED-COMPARISON TECHNIQUE

	Number of judges preferring each sample in each pair																			
Group	Butter	Margarine	Butter	Span 65	Butter	Span 85	Butter	GMO[d]	Margarine	Span 65	Margarine	Span 85	Margarine	GMO	Span 65	Span 85	Span 65	GMO	Span 85	GMO
1	9	5	9	5	-	-	-	-	5	9	-	-	-	-	-	-	-	-	-	-
2	5	9	10	4	10	4	-	-	9	5	11	3	-	-	6	8	-	-	-	-
3	11	3	9	5	11	3	-	-	9	5	9	5	-	-	11	3	-	-	-	-
4	9	5	10	4	-	-	9	5	7	7	-	-	6	8	-	-	8	6	-	-
5	8	6	-	-	9	5	11	3	-	-	8	6	9	5	-	-	-	-	5	9
6	10	4	7	7	-	-	10	4	8	6	-	-	8	6	-	-	10	4	-	-
7	9	5	-	-	9	5	-	-	-	-	7	7	-	-	-	-	-	-	-	-
8	7	7	-	-	10	4	7	7	-	-	9	5	8	6	-	-	-	-	8	6
9	8	6	-	-	11	3	-	-	-	-	10	4	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	6	8	6	9	5
Total	76	50[e]	45	25[e]	60	24[f]	37	19[e]	38	32	54	30[e]	31	25	25	17	26	16	22	20

TABLE V

TOTAL SCORES[g] OF EIGHT JUDGES FOR MARGARINE,[a] BUTTER[b] AND LOW-FAT SPREADS[c] WHEN COMPARED WITHIN EACH GROUP

Group	Butter	Margarine	Span 85	Span 65	GMO[d]
1[h]	33	39	-	36	-
2	34	32	40	38	-
3[k]	31	35	42	36	-
4	31	36	-	39	38
5	32	34	40	-	38
6[k]	31	36	-	35	42
7[h]	32	38	35	-	-
8	33	32	39	-	40
9[hk]	30	34	41	-	-
10	-	-	34	37	32

FOOTNOTES FOR TABLES IV AND V

[a]The margarine contained 79.4% fat, 2% Nacl, 16.4% water, and 2.2% curd.

[b]The butter contained 80% milk fat, 2% NaCl and water.

[c]The low-fat spreads contained 50% milk fat, 2% NaCl, water and either 1.0% Span 65, 1.8% Span 85 or 1.0% Glycerol mono-oleate (GMO) plus 0.25% oleic acid as emulsifier; these are identified by the emulsifier which they contained.

[d]Glycerol mono-oleate / oleic acid

[e]Statistically significant difference ($P < .05$) according to the tables of Roessler, Baker and Amerine (14).

[f]Statistically significant difference ($P < .01$) according to the tables of Roessler, Baker and Amerine (14).

[g]Each sample scored as "1" if preferred or "2" if not preferred.

[h]The group contained four samples, but the missing ones contained only 40% milk fat and analysis of these spreads was discontinued.

[k]Statistically significant difference ($P < .05$) according to Bradley's tables for rank analysis (6).

VITA

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