Development and marketing new dairy-based foods

DEVELOPMENT AND MARKETING NEW DAIRY-BASED FOODS

by

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ABSTRACT

The dairy industry of the United States has observed an increased use of solids-not-fat, while butter fat has become an excess, and somewhat unprofitable, dairy component. Ice cream offers a possible use of excess fat. Ice cream component levels, however, have been determined by executive decision rather than scientific information.

The principal objective of this study is to determine human discrimination for fat in vanilla ice cream. This information will provide a bias for future preference and demand studies for ice cream composition.

Four experimental designs are employed in the evaluation of discrimination ability for ice cream. Three of the four represent a traditional approach for determining sensory discrimination ability. The fourth design, applying the Theory of Signal Detection, has provided a very powerful method of obtaining bias-free statistical results.

The results of the study indicate that human subjects were able to discriminate not only fat content in ice cream, but overrun and flavor variables as well. The results of the TSD analysis showed the combination of fat, overrun, and flavor yielding the greatest taste richness. A brief production cost analysis shows the richest combination of ingredients with the least finished product cost contains 14 percent fat, 102 percent overrun and normal vanilla flavoring. The highest level of richness with the lowest cost may be obtained with 10 percent fat, 90 percent overrun, and no vanilla flavoring.

CHAPTER 1

INTRODUCTION

Producers of today's dairy products in the United States are faced with an excess of butterfat due to the increased use of solids-not-fat (SNF) in the production of fluid milk products. Finding profitable avenues to utilize the excess butterfat is an increasingly important issue. This situation has prompted this research organization to attempt to find the value of increased fat in vanilla ice cream.

The amount of fat in ice cream has been traditionally a decision of management. Many producers have preconceived notions of what constitutes a rich ice cream, while others simply produce the minimum limit fixed by law. In an era of quality consciousness, the optimum combination of ingredients in ice cream incorporating more fat could help an industry to determine the most profitable mix to produce. While the actual market preference of any product offered on the open market largely determines its demand, the study of human ability to discriminate various components of a product form a usable groundwork for future changes in product composition. Once discrimination ability is determined, the measurable preference for the product may be evaluated.

Purpose and Objectives

The purpose of this study is the determination of human discrimination ability for three components of ice cream; fat, overrun, and vanilla flavor. Beginning studies attempt to approach the fat variable employing the relatively limited paired comparison and triangle analytical designs. Later studies apply the Theory of Signal Detection to determine not only fat discrimination, but overrun and vanilla discrimination as well.

The major objective was to examine various analytical designs and corresponding statistical analysis that would best determine human sensory discrimination ability for ice cream.

Terms

The amount of fat in cream is determined by the fat content of cream from which the mix is produced. The percentage of fat incorporated determines whether or not the product may be called ice cream or ice milk. Most states have standards for fat content in ice cream similar to Arizona's 10 percent minimum.

The amount of air whipped into the ice cream is expressed as the percent overrun. The overrun level is a function of the increase in volume of the finished ice cream, and the volume of the mix used to produce the ice cream. In this study, higher levels of overrun connote higher overrun percentage levels. For example, 102 percent has more air per volume and, therefore, a lower total density. Lower overrun levels, 78 percent for example, is more dense, or stated differently, has less air per volume of finished product. Lower overruns will also weigh more than the higher overrun levels. Obviously, the lower overruns use more mix for every unit of finished ice cream and represent a higher cost per finished unit.

Review of Literature

A review of the recorded information specifically related to ice cream fat preference has produced two major studies. The first, by Williams and Campbell in 1923 could possibly be the classic ice cream preference study. The second, a work by Tracy in 1937, develops a more sophisticated method of testing but tends to arrive at an ambiguous conclusion.

The 1923 study by Williams and Campbell for the United States Department of Agriculture was entitled, "Effect of Composition on the Palatability of Ice Cream." The researchers tried a "new method of measuring the desirability of ice cream." According to the authors, previous research used the score card method for testing ice cream composition. The study includes several experiments on the three principal classes of solids in ice cream, namely, milk fat, milk solids-not-fat, and cane sugar. The milk fat section evaluates the effect of fat content on palatability of ice cream. Three mixes were prepared containing 12, 15, and 18 percent fat. All other constituents of the mix were held constant. The ice cream was sold to U. S. Department of Agriculture employees on each of four consecutive days. Prices of the ice cream were not varied according to its composition because the researchers believed "this would disclose the difference in quality and defeat the main purpose of the test." The test lasted three weeks and during that period, 67 people sampled the three mixes, purchasing over 500 samples. Only 27 of the purchasers were considered regular enough to tabulate their 316 total sales.

The first choice of the testers was the 18 percent fat mix representing 82 percent of the total sales. The 15 percent fat mix was second, having 10.4 percent of sales, followed by the 12 percent fat mix with only 7.6 percent of sales. The researchers deduced from these percentages that the "figures show conclusively that the rich ice cream was preferred by a large majority of the purchasers." (Williams and Campbell, 1923, pp. 3-5).

Another section of the study by the same investigators considered the influence of fat content on the quantity eaten. This study was made with 10 and 15 percent fat ice cream. Each of the 38 persons in the test were allowed to consume as much ice cream as he desired from a weighed can. After each of the five to seven persons in the individual test groups were satiated, the can was reweighed. Each fat level mix of the ice cream was tested at six different times. The researchers concluded from this study that "the fat content does not seem to have a great effect on the quantity of ice cream a person will eat, except perhaps when it is very rich." They found that the average consumption of ice cream in this test was 341 grams (1.2 pints) for the 10 percent fat and 317 grams (1.12 pints) for the 15 percent fat (Williams and Campbell, 1923, p. 7)

More than a decade later, Tracy, Professor of Dairy Manufacturers, University of Illinois, presented new information on fat preference to the 37th annual convention of the International Association of Ice Cream Manufacturers. Tracy recognized that scant written information of ice cream preference had been produced. His scientifically conducted research was an attempt to study consumer preferences for ice cream.

Primary data were obtained from a questionnaire delivered to almost 300 customers on the university milk route. The questionnaire was designed to detect basic consumer preferences and later served as a basis for a controlled laboratory test. Tracy observed that people had many false beliefs about ice cream. He suggested that "it would be very desirable to give the consumer a more accurate knowledge concerning ice cream in order to correct many of the false opinions which he now possesses." (Tracy, 1937, p. 61).

The second part of the study was controlled evaluation of consumer preferences. Nine tests were conducted using approximately 200 people. Children and persons with low income were excluded from the test in order to achieve a representative consumer buying group. Tracy explained his method of sampling at the question and answer session after the presentation of his paper. "The consumer was served in dishes. There were two variables, one was a round dish, and one was a square dish. In no case did we have more than three variables. One of the dishes was colored red so that there would be no opportunity or occasion to confuse them." (Tracy, 1937, p. 71).

Results of the test indicated that the majority of the women preferred the ice cream "having the heaviest, stickiest, and most resistant body." Tracy also states that for all tasters, "In the high (18 percent) vs. the medium (12 percent) fat test they were able to distinguish the difference in the bodies of the two ice creams and they preferred the body of the higher fat product." When the flavor of the ice cream was considered, however, the outstanding comment was a preference for the flavor of the less sweet, colder, medium fat content ice cream. Judging from these comments, Tracy concludes that "it did not seem that the tasters were able to deduce the factors that were being varied in the ice cream which they were testing." (Tracy, 1937, p. 68).

Sixteen years after Tracy presented his report at the Ice Cream Manufacturers convention, Mark Keeney, at the 49th convention, reaffirmed the value of butterfat research. Solids-not-fat were beginning to command greater attention while butterfat research was being pushed aside. "Future research on butterfat will pay a vital role in the prosperous progress of the dairy industry." (Keeney, 1953, p. 31).

Today, manufacturers seem to be using the lowest legal limit of milk fat in the ice cream they produce. An August 1972 issue of Consumer Report commented on the quality of 34 brands of ice cream produced in the midwest. The chemical analysis indicated that most of the ice creams sampled incorporated only 10 percent fat. Only two samples were above 13 percent butterfat.

Most of the midwest states sampled in the test have legal composition requirements similar to those adopted by Arizona. Vanilla ice creams produced in Arizona must contain at least 10 percent milk fat and weigh four and one-half pounds per gallon to be called ice cream (Arizona Revised Statutes, 3-625B, 1956). All those below the 10 percent limit are sold as ice milk. Flavored ice creams may contain as little as eight percent milk fat and be called ice cream.

CHAPTER 2

ANALYSIS OF PREVIOUS ICE CREAM PREFERENCE TESTS

The preceding chapter has shown that little research information exists for determining the optimum combination of ingredients in ice cream. As a result, it is quite possible that industrial ice cream ingredient combinations are frequently based on management decision rather than technical or scientific information. It was this absence of information that induced the Department of Dairy and Food Sciences to establish a program directed at determining the optimum combination of ingredients in ice cream. Conceptually, the program intended to measure the preference of human subjects for various levels of fat content above the minimum legal standard in Arizona (10 percent). Overrun was also included as a variable component, although no legal limit is placed on its incorporation in ice cream. These two variables were expected to expose some of the unknown preferences for various ingredient combinations of vanilla ice cream.

The test program began in the spring of 1971, incorporating three levels of fat (10, 12, and 14 percent) and three levels of overrun (78, 90, and 102 percent) in the ice cream. An additional variable, price, was included due to the nature of the sampling procedure. The Department of Dairy and Food Sciences supervises an ice cream and cheese sale every Wednesday as part of a fund raising program for the Dairy Science Club. The opportunity existed to ask the customers at this sale to sample a few containers of test ice cream before they purchased the sale ice cream. The sample ice cream and the sale ice cream were part of the same mix so that the customer could taste each variation before making a purchase. The price of the sale product was varied according to the ingredient content. Lower overrun levels (less air) were priced higher due to the cost of increased density per volume of mix. Higher percentages of fat content were also priced higher.

During the club sale, each person desiring to sample ice cream was given three prepackaged cups containing enough ice cream for an adequate taste test. Each sample represented a different combination of ingredients, and was identified by a small color mark on the side of the cup. (Cups were semi-consistently color coded.) The subject indicated his preference by writing the color of the mark on the response form (Appendix A). After sampling the test ice cream, the subject could correlate the sample ice cream to the sale ice cream by requesting the same color mark on the sale product.

The test procedure (Table 1) shows that the experiment was divided into two major groups. The first group tested the preference for ice cream when fat was varied at the 10, 12, and 14 percent levels, and overrun incorporated at the 90 percent level. Price for the sale ice cream was $1.50 during the first four weeks. The amount of fat in the ice cream determined the price during the second four-week period.

The second major group measured the preference for three levels of overrun in ice cream. The amount of fat was consistently incorporated at the 12 percent level, while overrun was varied at the 78, 90,

Table 1. Department of Dairy and Food Sciences Test Procedure

Week of Test	Percent Fat	Percent Overrun	Price Charged Per Gallon
1-4	10	90	$1.50
	12	90	1.50
	14	90	1.50
5-8	10	90	1.40
	12	90	1.50
	14	90	1.60
9-12	12	78	1.50
	12	90	1.50
	12	102	1.50
13-16	12	78	1.60
	12	90	1.50
	12	102	1.40
17-20	10	90	1.50
	12	90	1.50
	14	90	1.50
21-24	10	90	1.40
	12	90	1.50
	14	90	1.60

and 102 percent level. The sale ice cream was priced at $1.50 for all levels of overrun during the first four weeks of the test group. In the second four weeks, the price for the ice cream was charged according to the overrun level.

The preference tests in the 17th through the 24th weeks were repetitions of the tests conducted in the first group.

The analysis of variance (ANOVA) is the usual statistical tool employed for data where knowledge of the variance is required in the experiment. In studies of consumer preference, however, the data are not likely to be normally distributed. This implies that the assumptions necessary for the application of ANOVA are not valid. To overcome this difficulty, a nonparametric statistical method is employed where no assumption of normality is required (Friedman, 1937).

The Friedman nonparametric simultaneous rank test is applied where a two-way classification exists with only one observation per cell (Miller, 1966). It is used for testing the hypothesis that the samples in the experiment were drawn from the same population. The test is particularly useful for this test because differences between subjects can often be larger than the subject's response to the different ice cream mixes.

The ranked data from the consumer response forms were cast in a two-way table having C columns and R rows. The rows represent individual subjects and the columns represent the different mixes. There are $(C!)^R$ distinguishable arrangements of ranks in the entire table. To each $(C!)^R$ is a corresponding value of

$$S = \sum_{i=1}^{C} \left[T_i - \frac{R(C+1)}{2} \right]^2$$

where T_i = sum of the ranks in each treatment (column),
C = number of columns or treatments,
R = total number of rows (Bradley, 1968, p. 124).

When the value of S exceeds the number of distinguishable arrangements of ranks in the entire table (α-sized upper tail), the differences between columns (treatments) are statistically significant. Tables are available that list exact critical values of S when the number of rows are small. When R is large, as it was in the experiment, the Friedman test statistic (Bradley, 1968, p. 126).

$$X_r^2 = \frac{12S}{RC(C+1)}$$

may be compared directly to chi square tables with C-1 degrees of freedom (Bradley, 1968). If a significant difference is detected by X_r^2, the statistic (p. 126)

$$\overline{R} - \overline{R} \, q_k^\alpha \infty \sqrt{\frac{C(C+1)}{12R}}$$

is a simultaneous test to determine which of the treatments (column means) are different. The constant $q_k^\alpha \infty$ is the upper α level of the unit normal random variable, C (Miller, 1968, p. 174).

The Friedman chi square statistic was calculated for the data representing each four-week test period. Significant values were obtained in all but a few cases. The data were further analyzed for significant mean treatment differences.

The first four weeks of the test attempted to determine the preference for the three fat levels when price and overrun were held constant. The resulting X_r^2 indicates a strong preference response by the test participants. While no preference was significant between the 10 and 14 percent fat mixes, the subjects did show significant preference between the 10 and 12 percent fat, and the 12 and 14 percent fat. The 12 percent was the first choice, followed by the 10 percent and, lastly, the 14 percent (Table 2).

The 17-20th weeks duplicated the test conducted the first four weeks, The results show that no sample mix (treatment) was preferred significantly over the other.

The price of the sale ice cream was varied in the 5-8th and 21-24th weeks according to the amount of fat which was incorporated. As in the previous tests, overrun was held constant (90 percent), and fat was maintained at the 10, 12, and 14 percent fat levels. The results from the 5-8th weeks indicate that the 12 percent mix was the first choice in terms of numbers of responses only. Statistically, the higher priced 12 and 14 percent were not different. The first (12 percent) and third (10 percent) choices were statistically different as well as the second (14 percent) and third choices. The 21-24th weeks showed a shift of first preference from the 12 percent to the 14 percent fat. The shift, however, is representative of the numbers of responses only, and is not statistically significant. With this in mind, the results of the two test groups are exactly the same.

Table 2. Results of the Preference Test.

Week	Number in Test	Critical Value 5%	χ_r^2 Value	Fat	Overrun	Price	Preference Rank	Difference Between Means		Critical Value
1-4	308	5.99	21.37	10	90	1.50	2			
				12	90	1.50	1	.217 .370	.153	.199
				14	90	1.50	3			
17-20	197	5.99	4.40	10	90	1.50	3			
				12	90	1.50	2	.010 .178	.188	.281
				14	90	1.50	1			
5-8	183	5.99	15.50	10	90	1.40	3			
				12	90	1.50	1	.383 .060	.323	.245
				14	90	1.60	2			
21-24	144	5.99	10.79	10	90	1.40	3			
				12	90	1.50	2	.312 .002	.384	.274
				14	90	1.60	1			
9-12	206	5.99	6.92	12	78	1.50	1			
				12	90	1.50	3	.257 .155	.102	.281
				12	102	1.50	2			
13-16	91	5.99	1.06	12	78	1.60	3			
				12	90	1.50	1	.132 .132	.000	.347
				12	102	1.40	2			

When the price of the sale ice cream was varied according to ingredient density, the subject was aware of the three price levels and able to discriminate between the price differences. Consequently, there is a possibility that the lack of systematic differences in the results may be due to subjects identifying higher priced ice cream with a superior product rather than their actual preference. Further confounding of the results may have resulted from the use of color marks for identification of the sample and sale products. In this instance, the subject would have indicated his color preference rather than taste preference.

The results of this experiment have made it clear that the test subject's ability to declare a preference must be questioned. Even though the test has shown the choices of preferences to be greater than those due to chance or random choice, evaluation is not complete without knowing whether the differences are real or imagined. Therefore, the following chapters in this thesis attempt to determine the discrimination ability of the human subject for specific levels of fat, overrun, and flavor content.

CHAPTER 3

TRIANGLE AND PAIRED COMPARISON TESTS

The previous chapter described the preference tests conducted by the Department of Dairy and Food Sciences. These tests were based on the assumption that those people sampling the ice cream could discriminate fat content. The literature reviewed, however, does not indicate that any discrimination investigations have been conducted to support the assumption. Consequently, an assay of the validity of the assumption was necessary. The following sections deal with two methods of measuring discrimination ability, namely the triangle and paired comparison methods.

While the triangle test may be relatively less sensitive than the paired comparison (Byer and Abrams, 1953), the paired comparison test is more difficult to interpret when the differences between sample treatments are small. This is because no means exist to determine whether the differences the test subject tastes are real or imagined (Merck, 1963). The triangle test, however, overcomes the imagined difference problem in discrimination experiments by utilizing three samples, two of which are the same and one different. The test subject is required to distinguish which of the three samples is different. If a subject guesses, he has one chance in three of correctly identifying the odd sample (Merck, 1963).

The subjects to be tested by the triangle method were recruited from two groups of people; the Senior Citizens meeting club and the customers from the University community who purchase weekly ice cream produced by the Department of Dairy and Food Sciences. Ice cream for the Senior Citizens club was transported to the meeting hall and distributed in groups of approximately one hundred persons each. Participants at the ice cream sale were simply asked to sample the test ice cream before purchasing the sale product. In both tests the subject received a response form (Figure 1) and three samples, two of which were the same fat level, and one of a different fat level. Subjects were instructed to compare each sample and select the one which was different (Figure 1, Question 2).

Question 1 (Figure 1) served primarily as an alternate for the usual triangular response method by having the subjects give a rating to the difference in the ice creams tested. (If a subject could discriminate, the rating for the two different samples would produce a significantly higher statistical value than the two samples that were the same.) Ideally, the two samples of equal fat levels would receive a "no difference" rank while the comparison between samples of different fat levels would receive a "great" rating.

The remaining questions on the response form proposed to identify the ice cream consumption pattern of the subject participating in the test.

Response information was accumulated for all questions and all participants. Question 2 was merely recorded as a correct or incorrect response.

PLEASE MARK THE APPROPRIATE SPACE

1. Compare sample 86 to sample 16
   The difference is:
   - Great [ ]
   - Moderate [ ]
   - Slight [ ]
   - Very slight [ ]
   - No difference [ ]

   Compare sample 86 to sample 75
   The difference is:
   - Great [ ]
   - Moderate [ ]
   - Slight [ ]
   - Very slight [ ]
   - No difference [ ]

2. The three ice cream samples are exactly the same except that one has a different level of milk fat.

   Please indicate the one which is different. #________

3. Do you eat this type of ice cream
   - a. Daily? [ ]
   - b. Weekly? [ ]
   - c. Monthly? [ ]
   - d. Never? [ ]

4. Do you purchase ice cream
   - a. Daily? [ ]
   - b. Weekly? [ ]
   - c. Monthly? [ ]
   - d. Never? [ ]

5. Do you purchase ice cream for
   - a. Self [ ]
   - b. Family [ ]
   - c. Friends [ ]
   - d. Other [ ]

Figure 1. Response Form for Triangle Test.

The chance expectation that a subject will pick the odd sample in this test is .333 (Byer and Abrams, 1953, p. 186). The number of correct selections in excess of the chance expectation will determine whether the test was significant. The number of standard deviations or "α" units of the binomial population is determined by the following formula:

$$\text{Std. deviations} = \frac{(n \pm .5) - Np}{\sqrt{Npq}}$$

where N = total number of tasters,

n = actual number of correct choices,

p = probability of a correct choice by chance,

q = probability of an incorrect choice by chance,

Np = number of correct selections expected by chance,

(Siegel, 1956, p. 4).

All values above 1.65 will be statistically significant and indicate the number of correct selections was greater than the number due to chance alone. Furthermore, a significant test value will also indicate that the subjects were able to tell the difference between fat levels in ice cream.

Each response in Question 1 was accumulated by rank order and treated to the standard analysis of variance.

The analysis of variance conducted for Question 1 did not disclose any significant statistical difference for any fat level. In fact, both test subject groups ranked all the samples between 2 and 3 (slight and moderate difference). No distinction was made between the samples which were the same content and the samples with different contents. The samples which were different produced a higher, but not significant rank. Evidently, the subjects could not detect the difference between fat levels.

Table 3 presents the results of Question 2. Once again, the computed values were not statistically significant.

The last three questions merely indicated that ice cream was purchased primarily for self and friends and consumed and purchased on a weekly to monthly basis.

Paired Comparison Test

The paired comparison is one of the least complicated methods of determining sensory discrimination and possibly is more sensitive than the triangle method. This section describes the use and method of analysis of this test incorporating elementary school children as the test subjects.

The paired or two-sample test is based on the act of making a choice between alternatives. Its simplicity makes it especially useful when dealing with small children. The test method requires that two stimuli be presented either simultaneously or successively. The subject is asked to judge the two samples according to some predescribed attribute (Merck, 1963).

Each subject was given two color coded containers (the containers were consistently coded), a response form, and instructed to determine which of the two samples was richer.

The Department of Dairy and Food Sciences provided the two ounce samples. Since the paired comparison test requires only two

Table 3. Triangle Test Results.

Fat Content	Number of Correct Selections	Number of Incorrect Selections	Total	Percent Correct of Total	Percent Expected Correct	Standard Deviation	Critical Value (5% Confidence Level)
			Senior Citizens Meeting Club				
10-10-12	31	48	79	39.2%	33-1/3%	1.12	1.65
12-12-14	8	10	18	44.4%	33-1/3%	1.00	
14-14-10	20	44	64	31.3%	33-1/3%	0.35	
			161				
			Ice Cream Weekly Sales				
10-10-12	9	9	18	50.0%	33-1/3%	1.50	1.65
12-12-14	8	9	17	47.1%	33-1/3%	1.21	
14-14-10	10	16	26	38.5%	33-1/3%	0.56	
			61				

samples be used, the three fat levels were employed as pairs of 10 and 12 percent fat, 10 and 14 percent fat, and 12 and 14 percent fat.

Analysis

Data were relative frequencies of choice of the two samples and were subsequently accumulated for all subjects participating in the test.

The chance expectancy of selecting the richer of the two samples presented is .5 or one chance in two. The number of correct selections in excess of the chance expectation will determine whether the discrimination was significant. The statistical method utilized for computing the standard deviation is the same as used for the triangle test.

Results

Table 4 presents the values obtained from the paired test. Note that the number of correct selections in any case did not exceed the number of selections required to make the test significant. Apparently, the children were not able to differentiate among the samples.

A preference test was concurrently conducted with the paired comparison discrimination test. The subjects were asked to indicate their preference by circling the color on the cup representing the ice cream mix which they liked best. Table 5 presents the results of this test. The only difference found to be significant at the five percent level of significance was the preference stated for the 12 percent fat in the 10-12 percent sample pair.

Table 4. Paired Comparison Test Results.

Fat Content	Number of Correct Selections	Number of Incorrect Selections	Total	Percent Correct of Total	Percent Expected Correct	Standard Deviation	Critical Value (5% Confidence Level)
10-12	43	32	75	57.3%	50%	1.27	1.97
10-14	48	34	82	58.5%	50%	1.55	1.97
12-14	47	40	87	54.0%	50%	.74	1.97

Table 5. Ice Cream Preference Results.

Percentage Fat in Ice Cream	Number of Subjects Indicating Preference	Percentage of Total
10%	28	37.3%
12%	47	62.7%
10%	46	56.1%
14%	36	43.9%
12%	40	47.1%
14%	45	52.9%

This chapter has presented tests employing the paired comparison and triangle methods. The tests were conducted under controlled conditions. Yet, in all tested cases of ice cream fat combinations, no systemmatic evidence of fat discrimination exists. Thus, three possible conditions exist: 1) the test subjects are not able to discriminate fat levels; 2) the test methods are not sensitive to the small variances; 3) individual taste biases may be masking the method of analysis.

The next chapter is an attempt to investigate these conditions through a newly applied statistical method referred to as the Theory of Signal Detectability. TSD is able to isolate individual response biases and still be sensitive to important changes in the design variables. This method was used to test the discriminatory ability of the human subject for not only fat levels in ice cream, but overrun and flavor levels as well.

CHAPTER 4

HUMAN DISCRIMINATION ABILITY IN ICE CREAM

A recent theoretical methodological advance based on the Theory of Signal Detectability (TSD), developed by Green and Swets (in Wheeler et al., 1971) has provided techniques for distinguishing between the effects of perceived characteristics of the stimulus and influence of the observer's decision criteria. Their work provided the experimental design for the last tests discussed in this chapter. The TSD approach has been successful in evaluation of simple psychophysical judgments according to Hake and Rodwan (in Wheeler et al., 1971), recognition memory performance as per Daniel et al., 1972, and also Egan, 1958 (in Wheeler et al., 1971), perception of degraded visual images (Wheeler, Daniel, Seeley, and Swindell, 1971), and perceptual evaluation of natural landscapes (Daniel, Wheeler, Boster, and Best, 1972).

The sensory discrimination of ice cream fat levels is very much like any other psychophysical task. The subject is presented with a physical stimulus array and is asked to make a sensory judgment. The subject's experiences with ice cream contribute to the sensory standards of the taster and his established decision criteria regarding the richness of an ice cream mix (Daniel, Wheeler, Boster, and Best, 1972). The conditions in which the judgment must be made and the context in which the sample is presented will also influence the rating. To this point, the research methodologies utilized in this thesis have not considered the decision criteria of the test subject. Tests discussed in the preceding chapter have forced the subject to respond on a yes or no basis. The following methodology circumscribes the limitations of forced choice and at the same time, eliminates the individual decision bias that may exist.

The following is an application of TSD analysis to evaluate the human discrimination ability for ice cream fat levels. While fat discrimination was the primary objective, the application of TSD computer analysis allowed analysis of the interactions of two additional variables, overrun and flavor. Overrun and flavor were hypothesized to be the most likely ingredients to interact with milk fat in determining the richness of a mix.

Twenty-seven mixes of ice cream were prepared with each of the three variables incorporated at three levels. Table 6 is a display of the 27 mixes and the respective levels of each variable. The mix designations represent the three variable ingredients; fat, overrun, and vanilla flavor. The LMM, for example, contained the lowest fat level (10 percent), the medium overrun level (90 percent), and the medium vanilla level (normal vanilla). The vanilla flavoring was incorporated at the normal level of 25 ounces per 10 gallons of mix (two fold), below normal level of zero vanilla, and an above normal level of three times the normal level of vanilla.

Test Procedure

Four of the 16 subjects participated in each test session which was held at the University dairy plant. The subjects were isolated in

Table 6. Ice Cream Mixes--Ingredient Combinations.

Mix	Fat Percent	Overrun Percent	Vanilla
LHL	10	102	L
MHL	12	102	L
HHL	14	102	L
LML	10	90	L
MML	12	90	L
HML	14	90	L
LLL	10	78	L
MLL	12	78	L
HLL	14	78	L
LHM	10	102	M
MHM	12	102	M
HHM	14	102	M
LMM	10	90	M
MMM	12	90	M
HMM	14	90	M
LLM	10	78	M
MLM	12	78	M
HLM	14	78	M
LHH	10	102	H
MHH	12	102	H
HHH	14	102	H
LMH	10	90	H
MMH	12	90	H
HMH	14	90	H
LLH	10	78	H
MLH	12	78	H
HLH	14	78	H
	10=L 12=M 14=H	78=L 90=M 102=H	

specially prepared booths equipped with sample response forms, rinse water and instruction forms (Appendix A). The test sessions were conducted in both mornings and afternoons for approximately one week. After sampling nine mixes of ice cream, the test subjects were permitted a five minute rest period before proceeding to the next group. The subject sampled a total of 81 mixes distributed over three sessions where 27 samples were presented per session.

Samples were presented in random order, one sample at a time every 45-50 seconds in order to preserve the independence of sample judgments. The subjects indicated the degree of the sample's richness by recording a number from zero to nine on the response form. To establish the range of richness, the subject received two anchor samples at the beginning of every test session. One sample contained the three lowest levels of each variable; 10 percent fat, 102 percent overrun, and no vanilla flavor. The other sample contained the three highest levels of each variable; 14 percent fat, 78 percent overrun, and three times the normal vanilla flavor. Subjects were not instructed as to which sample was richest. Rating responses were subsequently keypunched and statistically analyzed by computer.

The Department of Dairy and Food Sciences provided all 27 mixes packed in two ounce plastic containers. The containers were identified by a randomized number set which provided no clues to the subject as to the nature of the mix.

The test panel was composed of six female and 10 male participants recruited from the Department of Dairy and Food Sciences, Psychology Department and Agricultural Economics Department. None of the subjects had any prior experience on taste panels and none were acquainted with the experiment. Their average age was 27 years.

The ability of an observer to detect a signal (input) from noise (other background inputs or stimulus events) is described by the observers Receiver Operating Characteristic (ROC). The ROC is a bivariate function relating the observer's "Hit Rate" (HR) and "False Alarm Rate" (FAR). The HR is an observer's tendency to respond "signal" when a signal was in fact presented. The FAR represents the observer's tendency to respond "signal" when in fact no signal (noise only) was presented. The ROC function is used to provide an estimate of the distance between the hypothetical noise distribution and the hypothetical signal-plus-noise distribution (Wheeler, Daniel, Seeley, and Swindell, 1971).

The ROC is formulated by obtaining HRs and FARs for a number of decision criterion levels. This information is obtained from the observer in the form of a confidence rating for each judgment. The confidence scale allows the subject to report his decision by a 10 point scale, thus reducing the limiting effect of a forced choice procedure. The rating scale applied in this experiment (Figure 2) ranged from nine, meaning that the subject was absolutely certain the ice cream tasted rich to zero, meaning that the subject was absolutely certain the ice cream sample was not rich. A judgment of absolute certainty of richness implied that the subject had decided the ice cream was rich (or not rich) under his most rigorous decision criterion. A judgment of a lower confidence level would indicate that the ice

9	ABSOLUTELY CERTAIN - RICH
8	MORE THAN "FAIRLY CERTAIN"- RICH
7	FAIRLY CERTAIN - RICH
6	MORE THAN "JUST GUESSING" - RICH
5	JUST GUESSING - RICH
4	JUST GUESSING - NOT RICH
3	MORE THAN "JUST GUESSING" - NOT RICH
2	FAIRLY CERTAIN - NOT RICH
1	MORE THAN "FAIRLY CERTAIN" - NOT RICH
0	ABSOLUTELY CERTAIN - NOT RICH

Figure 2. Certainty-of-Response Scale, Degrees of Certainty.

cream could have been accepted as rich only under a less rigorous criterion level (Wheeler, Daniel, Seeley, and Swindell, 1971).

Daniel, Wheeler, Boster, and Best (1972) have shown that a "signal" versus "noise" distinction is not necessary to the TSD method. Any two stimuli can provide the basis for ROC function, the designations of HR and FAR being arbitrary. In the present study, the MMM mix was used as the basis (HR) for ROC functions. An ROC function relating the number responding at each criterion level between MMM and each of the other mixes was obtained by this procedure. It is the unique characteristic of TSD analysis that enables all the test responses to be represented on an equal basis, the individual response bias having been eliminated.

The essential characteristics of the TSD model are presented in Figure 3. Each distribution represents a hypothetical population of responses for four ice cream mixes. Note that each distribution is located at some point on the perceived richness scale. Assuming the third distribution has been selected as the standard mix, the fourth distribution mean will be a specified number of units from the standard. The same applies to the means of the first and second distributions. In terms of ice cream discrimination, the greater the distance between means of the distributions, the greater the ability of the test subjects to discriminate mixes. The distribution means which lie close together (1 and 2, for example) indicate that the subjects rated the mixes in a similar manner. The dispersion inherent in each distribution is due to variation between individuals rating a mix, and variation in the perceptual processes of the individual from one observation

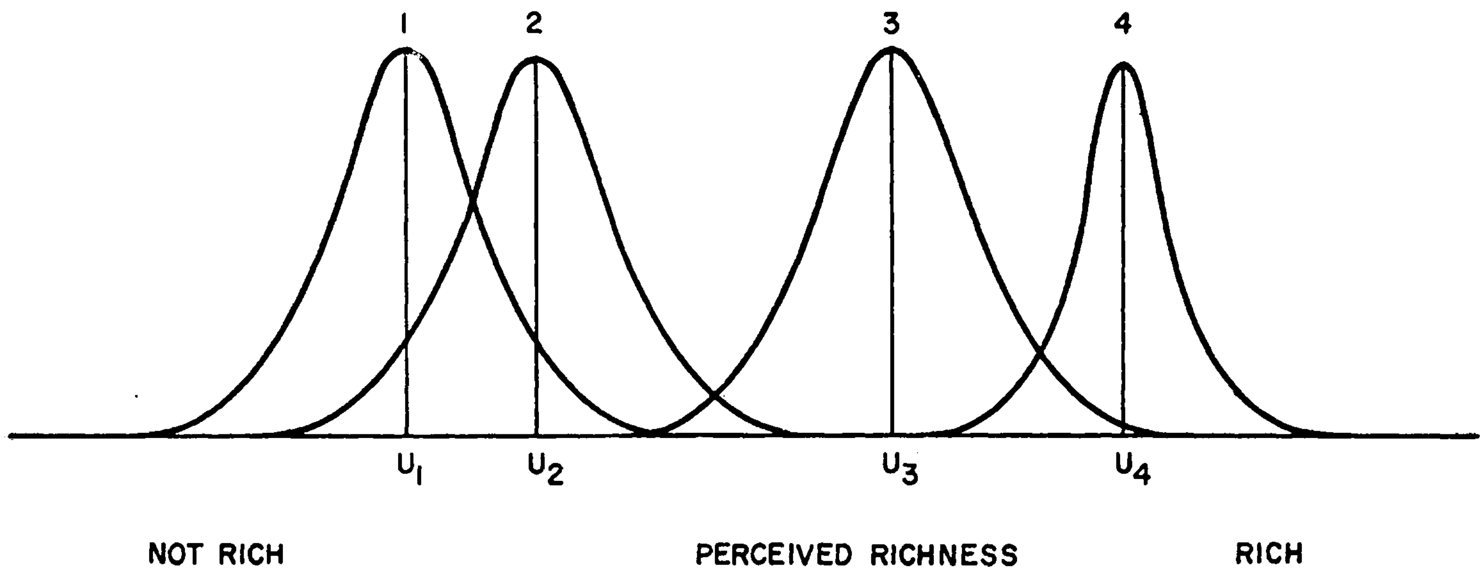

Figure 3. Characteristics of the TSD Model.

to the next. The fourth distribution, for example, represents a small variance and therefore, a closer agreement by the test subjects.

The individual TSD distributions (or ROC functions) may also be visualized by plotting the cumulative probabilities (obtained from the frequency of response for each confidence level) of the HR and FAR. Since the MMM mix was arbitrarily used to compute the HR, the standard mix (MMM) will, if plotted against itself, form a positive (45°) diagonal. The distance of the other ROCs from the diagonal establishes the degree of discrimination. The farther away the ROC function is from the diagonal, the greater the discrimination ability. Consequently, it is the distance measure that offers the desired information. Plotting the individual ROCs is unnecessary since the distance parameters may be determined directly from the data.

There are several distance parameters which may be used, each with its own advantages and disadvantages. The d_m distance parameter is the mean distance of the ROC from the positive diagonal. This distance measurement was selected for application in this test for the following reasons; it is less influenced by the slope of the ROC, it is an average value rather than being computed from arbitrarily selected points, and consequently, better able to reflect the actual observations (Wheeler, Daniel, Seeley, and Swindell, 1971).

Table 7 presents the data summed over all subjects and runs (number of repeat exposures to the same mix), for one ice cream mix (27 total) employed in the test. For each level of confidence exists a frequency of subject response. A distribution of this form is constructed for all 27 mixes of the test. The responses are accumulated

Table 7. Cumulative Probabilities and Z Scores (LLL Mix).

Confidence Level	f	cf	cp	Z
0	5	48	1.000	2.502
1	8	43	.896	1.257
2	6	35	.729	.608
3	7	29	.604	.262
4	4	22	.458	- .104
5	6	18	.375	- .316
6	8	12	.250	- .672
7	4	4	.083	-1.382
8	0	0	.000	-2.502
9	0	0	.000	-2.502
	48			

f = frequency

cf = cumulative frequency

cp = cumulative probability

Z = normal deviate

for each level on the confidence scale. For example, five responses were recorded for the "absolutely certain not rich" rating (0), while no responses were recorded for the "absolutely certain rich" (rating 9). The category frequencies are accumulated from the "absolutely certain rich" to "absolutely certain not rich" (9 to 0). From the cumulative probability data, each category is normalized by transforming the cumulative probabilities to normal deviates (Z scores). The resulting ROC for this particular mix may be compared directly to the standard mix by application of the d_m metric. (While any sample is eligible to be used as a basis of comparison, the MMM mix was selected due to its central position as a sample. This offered the TSD analysis more latitude to the extremes of the mix combinations.)

$$d_m = \text{Mean Z score for the standard mix (MMM)} - \text{Mean Z score for each mix, LLL in this example.}$$

The d_m value represents the distance in normal deviates that any particular distribution (or ROC) lies from the standard. Those distributions which lie above the standard for comparison will be represented by positive d_m values, while those below the standard will have negative d_m values.

Knowledge of the true nature of experimental response bias would be impossible without comparing the simple mean ratings and the TSD d_m indices. Since the value of the mean rating is a function of perceived richness and response bias, it may be contrasted to the d_m measure; a function of the perceived richness only. This is exemplified in the resulting order of the mixes test in this experiment (Table 8).

Table 8. Comparison of the Resulting Ordering of the Mean Rating Values and TSD, d_m Indices.

	Mean Rating	d_m
RICH	HHM	HHM
	HLH	HLH
	HHH	HHH
	HMH	HMH
	MMH	MMH
		MHH
	HLM	HLM
		MHM
	MLH	MLH
	MMM	MMM
	MHM	
	HHL	HHL
	MHH	
	HML	HML
		HLL
	MML	MML
	HLL	
	HMM	HMM
	MHL	MHL
	LMM	LMM
	LLH	LLH
	LML	LML
	LLM	LLM
	LMH	LMH
	MLL	MLL
	LHH	LHH
	LLL	
	MLM	MLM
	LHM	LHM
		LLL
NOT RICH	LHL	LHL

First letter of each three-letter sequence represents fat
(L - 10%, M = 12%, H = 14%)

Second letter represents overrun
(L = 78%, M = 90%, H = 102%)

Third letter represents flavor
(L = no vanilla, M = normal vanilla, H = three times normal vanilla)

The left hand side represents the results in terms of mean rating while the right hand side are mixes ordered by the TSD metric. Note that the mix orders are highly correlated (Spearman Rank Correlation Coefficient = .99) indicating the relative absence of response bias effects. Any exceptions (MHH, for example) may be attributed to the method by which the central tendency of each mix distribution is measured. The occurrence of a skewed distribution, due to an unbalanced distribution of rating responses, will cause the arithmetic mean to deviate from the mode in the direction of the skew. The TSD normalized data analysis measures the distance of each mean Z score (normal deviate) to the standard mix mean Z score and, consequently, responds differently.

The question of sensory discrimination ability for fat would be represented in this experiment by a significant difference between the three fat level mean values averaged across the overrun and flavor variables. The ability to discriminate overrun and flavor will also be represented by a significant difference between mean values.

The results of the TSD and mean rating analyses have both shown the test subjects were able to discriminate differences for all three variables. Figure 4 presents the results of the TSD method, and Figure 5 presents the results of the mean rating analyses. Both figures are plots of the d_m or mean rating value versus the fat content for all 27 mixes in the test. Note that in each figure a significantly positive slope is evident. The mean rating results indicate that the mean rating values are increasing as the fat content increases, and the subjects were able to distinguish the

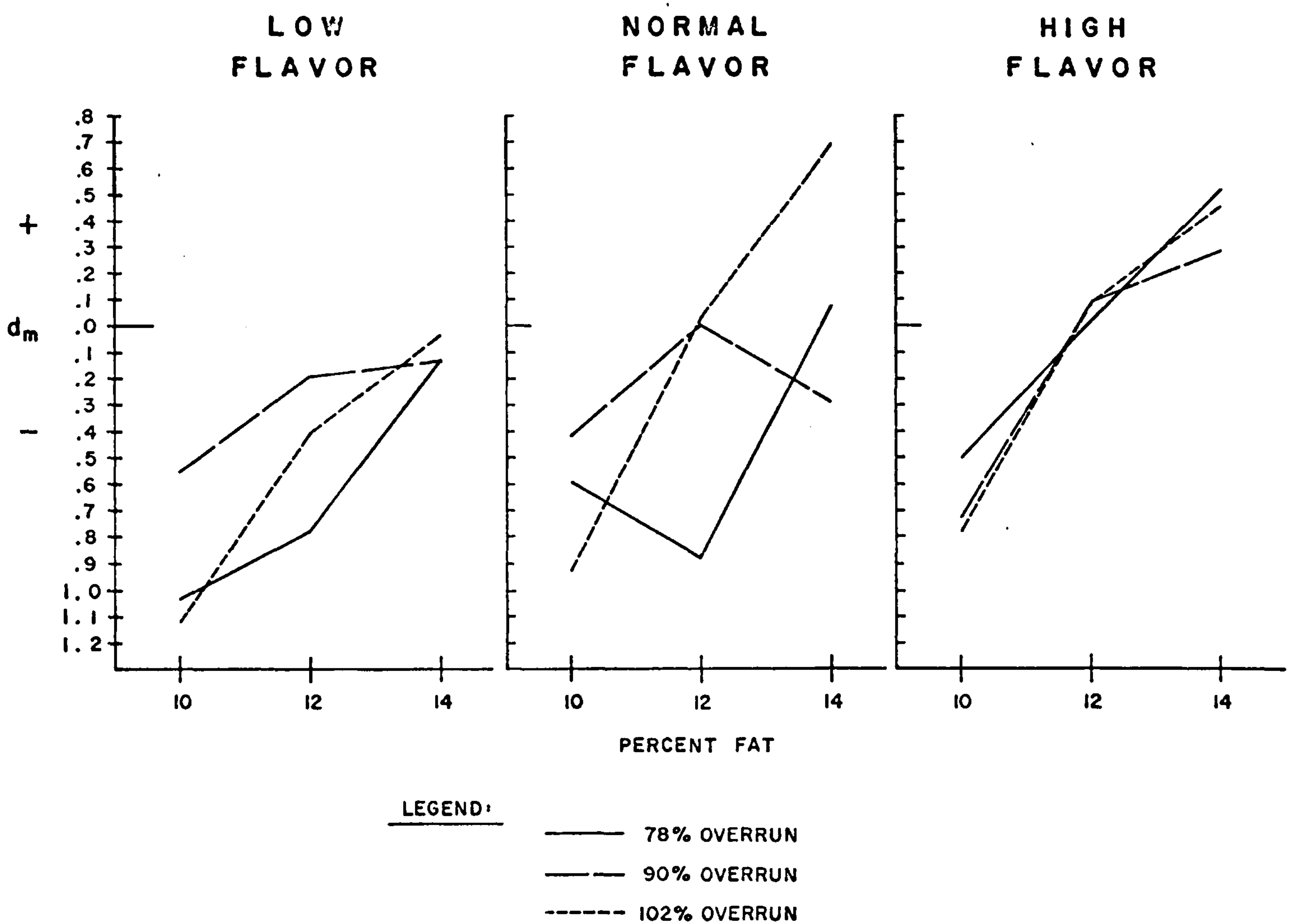

Figure 4. Results of the TSD Analysis (d_m Values).

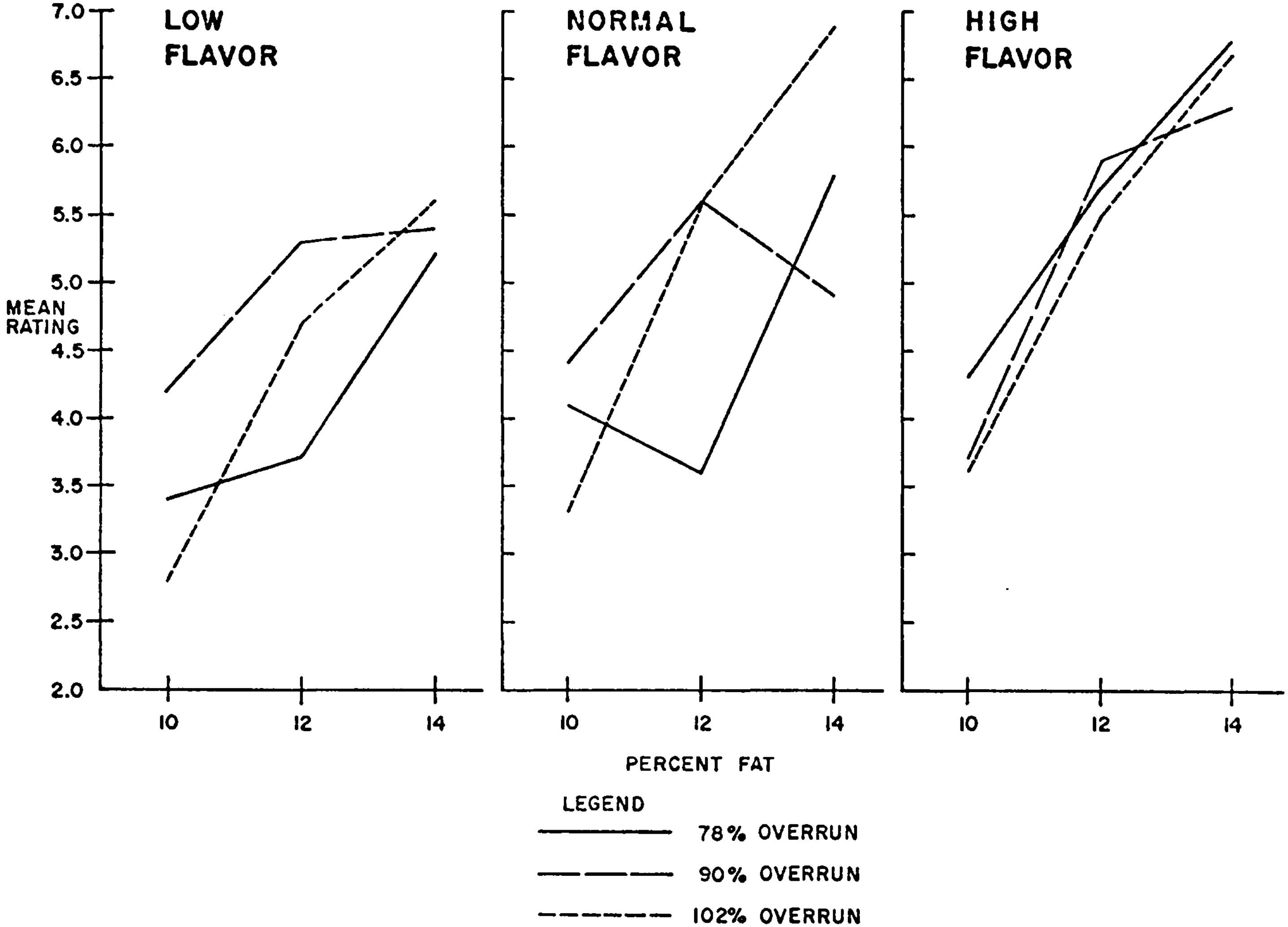

Figure 5. Mean Ratings for the 27 Mixes.

difference between fat levels. The d_m values in Figure 4 indicate the mean (positive or negative) distance from the standard mix 0 value (MMM). The more positive the value, the richer the mix tasted to the subjects.

The ability of the test subjects to discriminate fat levels may be clearly seen in the far left graph of Figure 6. This figure is a plot of the mean rating values versus the fat content values (10, 12, and 14 percent). As the level of fat is increased, the mean rating, or average richness value given to all mixes at only one level of fat, also significantly increases. Two observations are evident from this presentation: 1) the test subjects were able to discriminate the three levels of fat; and 2) the 14 percent fat ice cream was the richest tasting product. The 12 and 10 percent products were second and third, respectively.

The incorporation of extra flavor enhances the perceived richness of the ice cream. The right graph in Figure 6 represents the mean ratings of the three flavor levels incorporated in the test ice cream (all other variables have been summed). No significant differences were found between the normal flavor and zero flavor or normal flavor and extra flavor. However, the difference between zero flavor and extra flavor was significant and, in terms of perceived richness, the subjects could discriminate the incorporation of extra vanilla flavoring. Evidently, the higher flavoring produces a richer tasting ice cream.

The choice of the range of richness standards at the beginning of each experimental session (previously described) was based on the

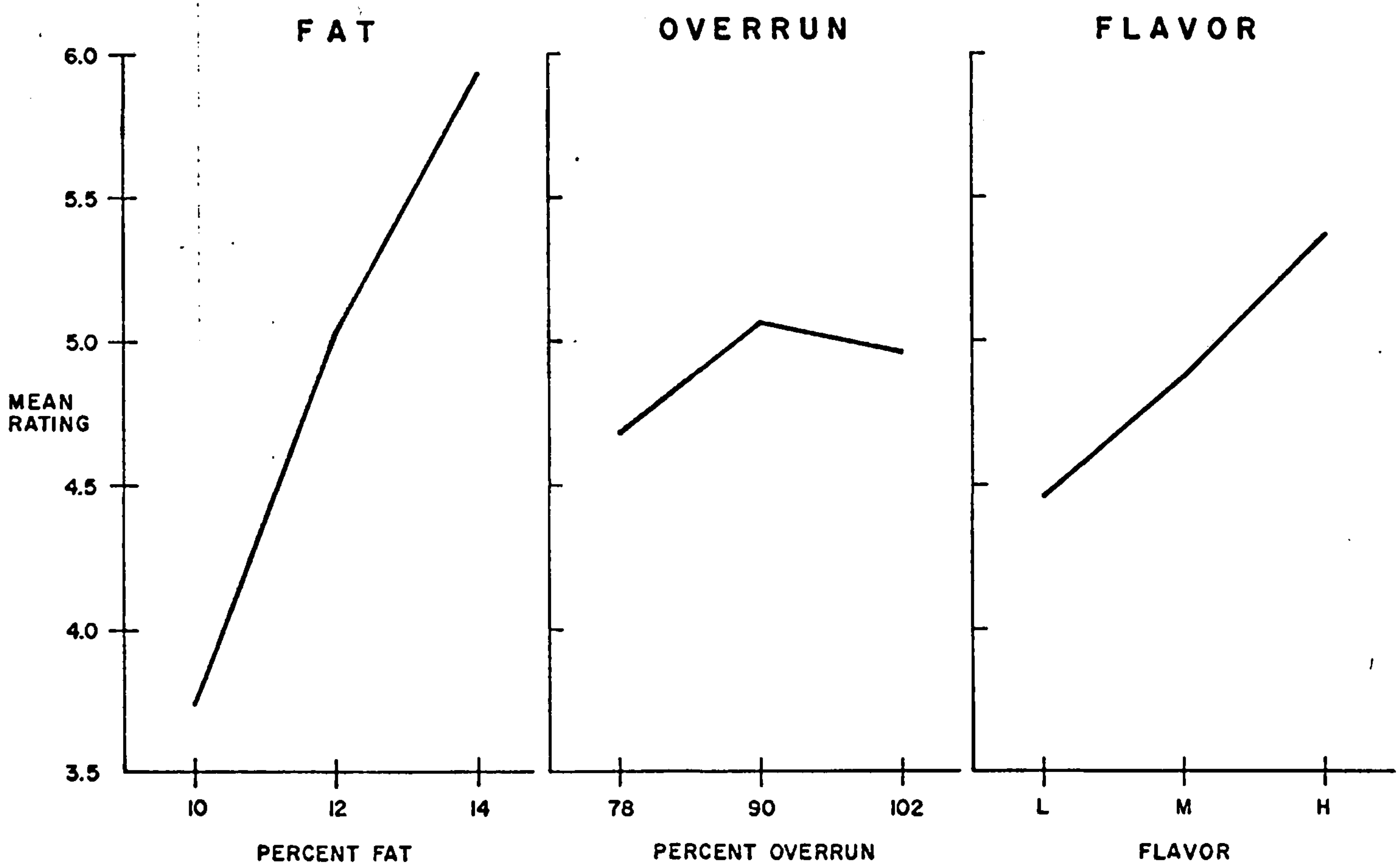

Figure 6. Mean Ratings for Each Variable Ingredient.

assumption that the lower percentage levels of overrun were richer due to their increased mix density (decreased air incorporation). The results of the experiment, however, do not indicate that the assumption was entirely correct. The middle graph in Figure 6 depicts the relationship between the three overrun levels and the mean perceived richness (all other variables have been summed). The 90 percent (medium) overrun was found to be significantly richer than the 78 percent overrun. The 102 percent overrun tends to be slightly richer than the 78 percent but the difference is not statistically significant (five percent level of significance). The 90 percent overrun is richer than both the 102 and 78 percent levels, but once again, only the 90-78 percent difference is significant. Consequently, if consideration is given only to overrun, the 78 percent does not produce a richer ice cream as previously assumed. It is the higher percentage levels that tend to produce a richer product.

The experiment also produced two other sources of variation, namely, the runs variance and subject to subject variance. The former is simply the difference in ratings from one run to the next (three runs total). This variance was not a significant part of the experiment.

The results of this investigation have only presented the independent sources of variation. The variables, however, may interact with each other, providing additional information about the ice cream mixes. Every possible combination of the variables has been analyzed by the analysis of variance method, and produced two statistically significant groups (five percent confidence level for all F values): fat and overrun, and flavor and overrun.

The Studentized range statistic and Duncan's new multiple-range test (Steel and Torrie, 1960) were applied in order to detect significant differences between the means of the interacting variables. The significant differences (five percent level of significance) noted were consistent for both tests.

The effects of the fat-overrun interaction are presented in Figure 7. The three fat levels are plotted against the mean rating for perceived richness (connecting vertical lines indicate no significant difference). Each approximately horizontal line represents the three different levels of overrun. Note that the mean rating increases with each level of increased fat. The importance of this graph may be appreciated by an examination of the individual points for each level of fat. At the 10 percent fat level, for instance, the 102 percent overrun was significantly less rich than the 78 and 90 percent overruns. The next level of fat (12 percent) tends to change the order of overrun and richness. The 78 percent overrun was significantly less rich than the 90 and 102 percent overruns. When the fat is 14 percent, the three levels of overrun did not seem to have any appreciable effect. The three points for the 14 percent fat are not statistically significant (five percent level).

Consider now the effects of the interaction of fat and overrun from a slightly different perspective. Figure 8 reverses the plotting order by placing the overrun percentage on the horizontal axis. Each line represents the three levels of fat. In this display,

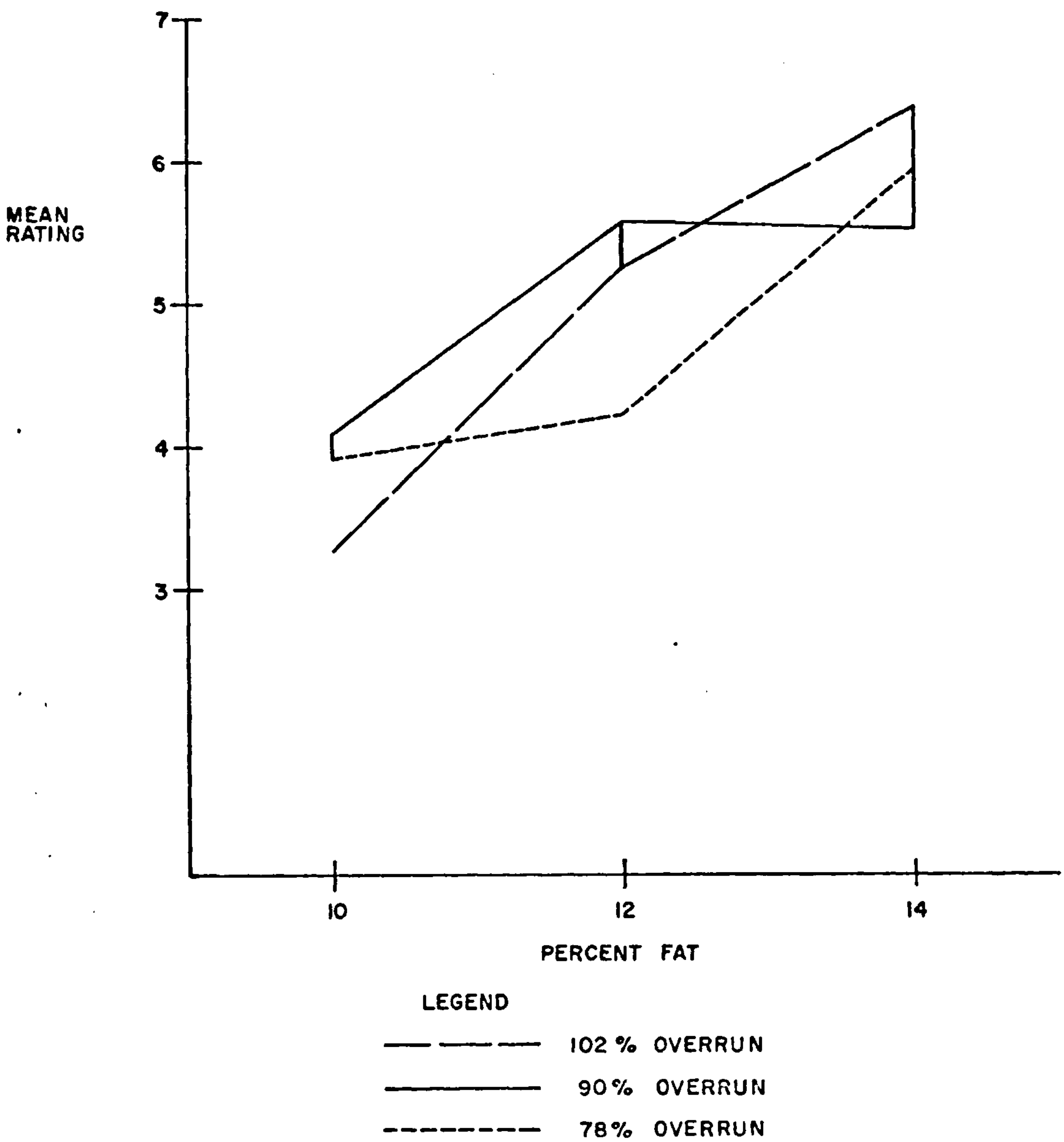

Figure 7. Fat-Overrun Interaction.

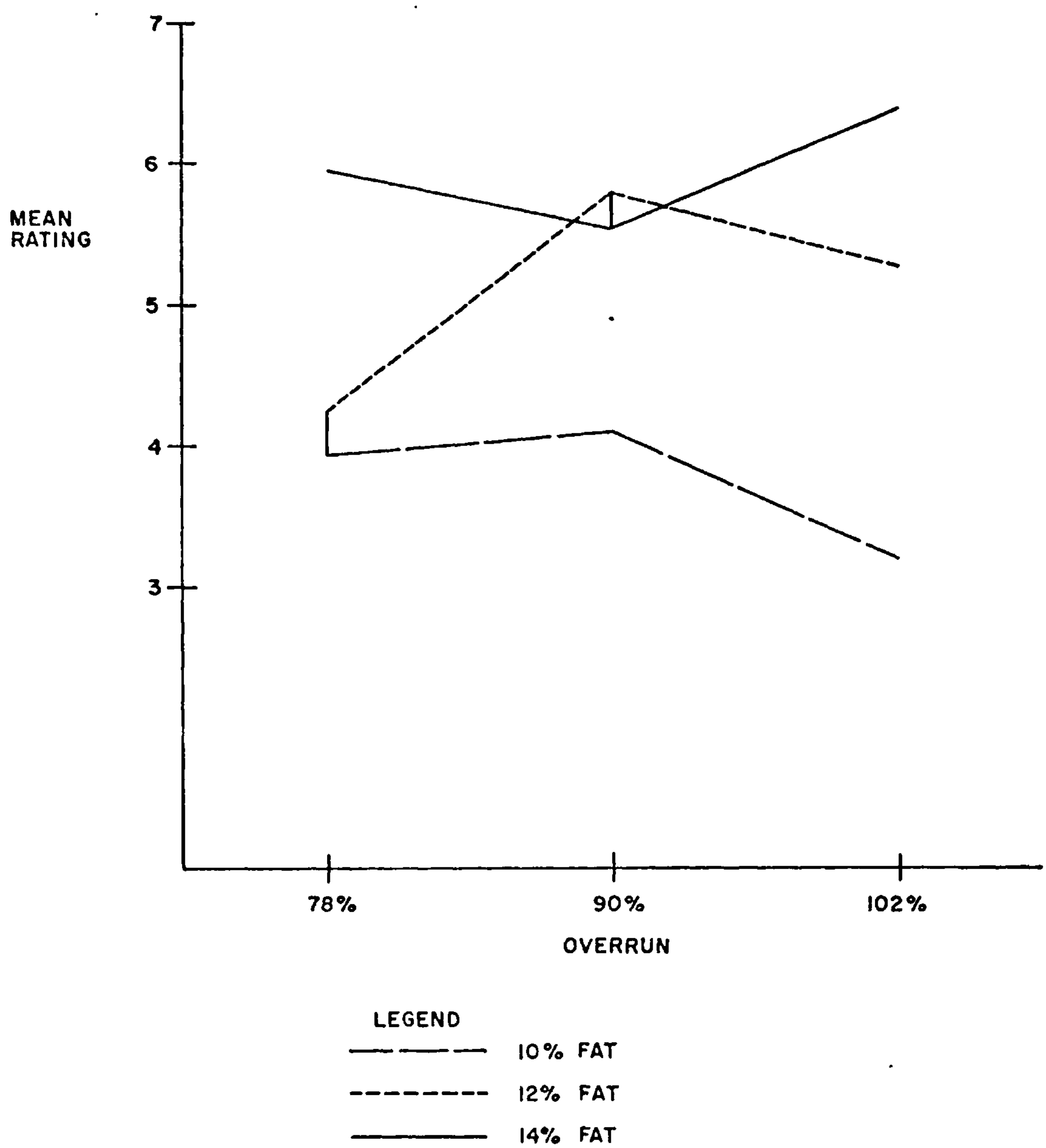

Figure 8. Overrun-Fat Comparison.

it is evident that the higher overrun levels tend to increase the richness of the ice cream (except the 12 percent fat). The 78 percent overrun was considered richer with the 14 percent fat, yet the 12 and 10 percent fat levels were statistically the same. When ice cream contained 90 percent overrun, the 14 and 12 percent fat did not show any statistical difference. The 10 percent fat, however, was significantly less rich. All three levels of fat were distinguishable when the ice cream contained the 102 percent overrun.

The last interaction to be significant in the test was the action of the vanilla flavoring and overrun level (Figure 9). The results indicate that the flavoring has the greatest effects at the 78 and 102 percent overrun levels. At both overruns, the highest vanilla produces a richer ice cream. The high flavor effect was most apparent at the 78 percent overrun while the low (zero) vanilla falls significantly below. Alternatively, the subjects were best able to distinguish the incorporation of flavor only at the high (102 percent) and low (78 percent) overrun.

Referring to Figures 4 and 5 once again, some general observations may now be applied to the practical considerations of mix ingredients. In both graphs, the increase of vanilla flavor tends to increase the richness of the mix; but note that the high flavor reduces the effects of overrun. The greatest overrun effects occur at the normal vanilla level. If 10 percent fat ice cream is a production goal, the overrun levels will be most important when normal vanilla is applied. This is partially true when no vanilla flavoring is used.

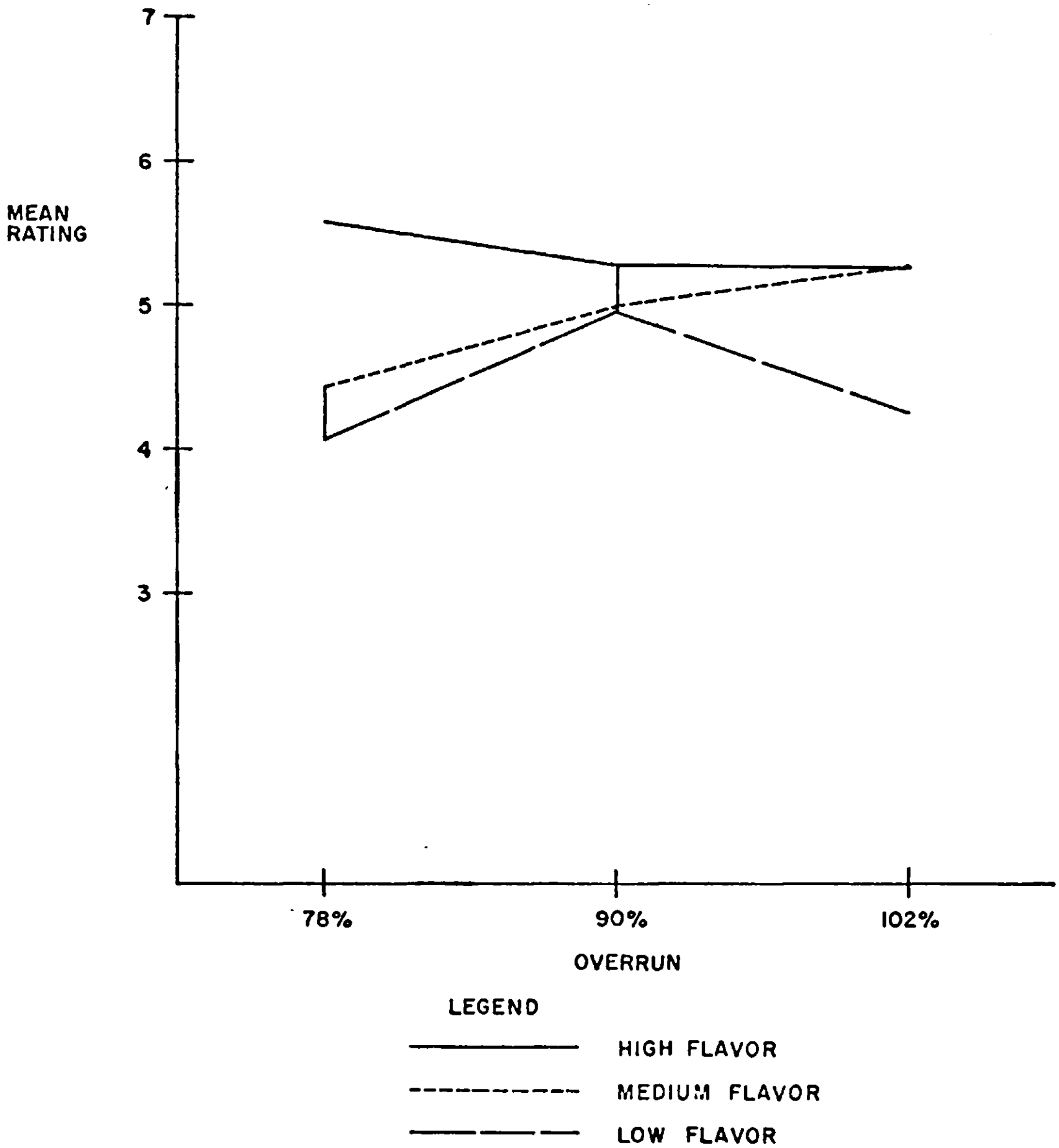

Figure 9. Vanilla Flavoring and Overrun Interaction.

The cost of the finished product is obviously a very important consideration to any production process. Based on current fat and vanilla prices, Table 9 presents the relative position of each mix in terms of the TSD (d_m) resulting richness rank. The numbers are ordered from least cost (1) to greatest cost (27). Perhaps the most interesting observation to be made from the table is that the richest perceived mix is not the highest cost mix. The effect of the high overrun (102 percent) has placed the cost of this mix within the range of the low fat mixes. From the standpoint of ice cream richness, the 14 percent fat, 102 percent overrun and normal flavor offers an intriguing possibility to commercial ice cream interests.

The review of the literature chapter (Chapter 1) produced evidence that the 10 percent fat ice cream is common for today's ice creams. The information presented on Figure 10 offers the optimum position in terms of cost and richness for all 27 mixes tested (prices represent current ingredient costs). Note that the low flavor and normal flavor with 10 percent fat and 90 percent overrun have been rated at nearly equal richness levels. The difference in cost (three cents per gallon), however, implies a significant savings available. Also note that the high flavor with 10 percent fat did not attain a richness rank any higher than the normal and low flavor mixes, but the price is substantially higher for the high flavor mixes.

The higher levels of fat and overrun and their corresponding prices also represent substantial cost advantages. Note once again the outstanding richness mix is not the highest cost product.

Table 9. Order of Richness (TSD Analysis) and Their Relative Cost Positions.

Mix	Cost Order	Current Cost Per Gallon of Finished Ice Cream
HHM	15	.77
HLH	27	.93
HHH	21	.82
HMH	25	.87
MMH	19	.80
MHH	14	.75
HLM	26	.87
MHM	8	.70
MLH	24	.85
MMM	13	.75
HHL	12	.75
HML	18	.79
HLL	23	.85
MML	9	.72
HMM	22	.82
MHL	4	.68
LMM	5	.69
LLH	17	.78
LML	3	.66
LLM	10	.73
LMH	11	.73
MLL	16	.77
LHH	6	.69
MLH	20	.80
LHM	2	.64
LLL	7	.70
LHL	1	.62

Cost ordered from lowest 1 to highest 27

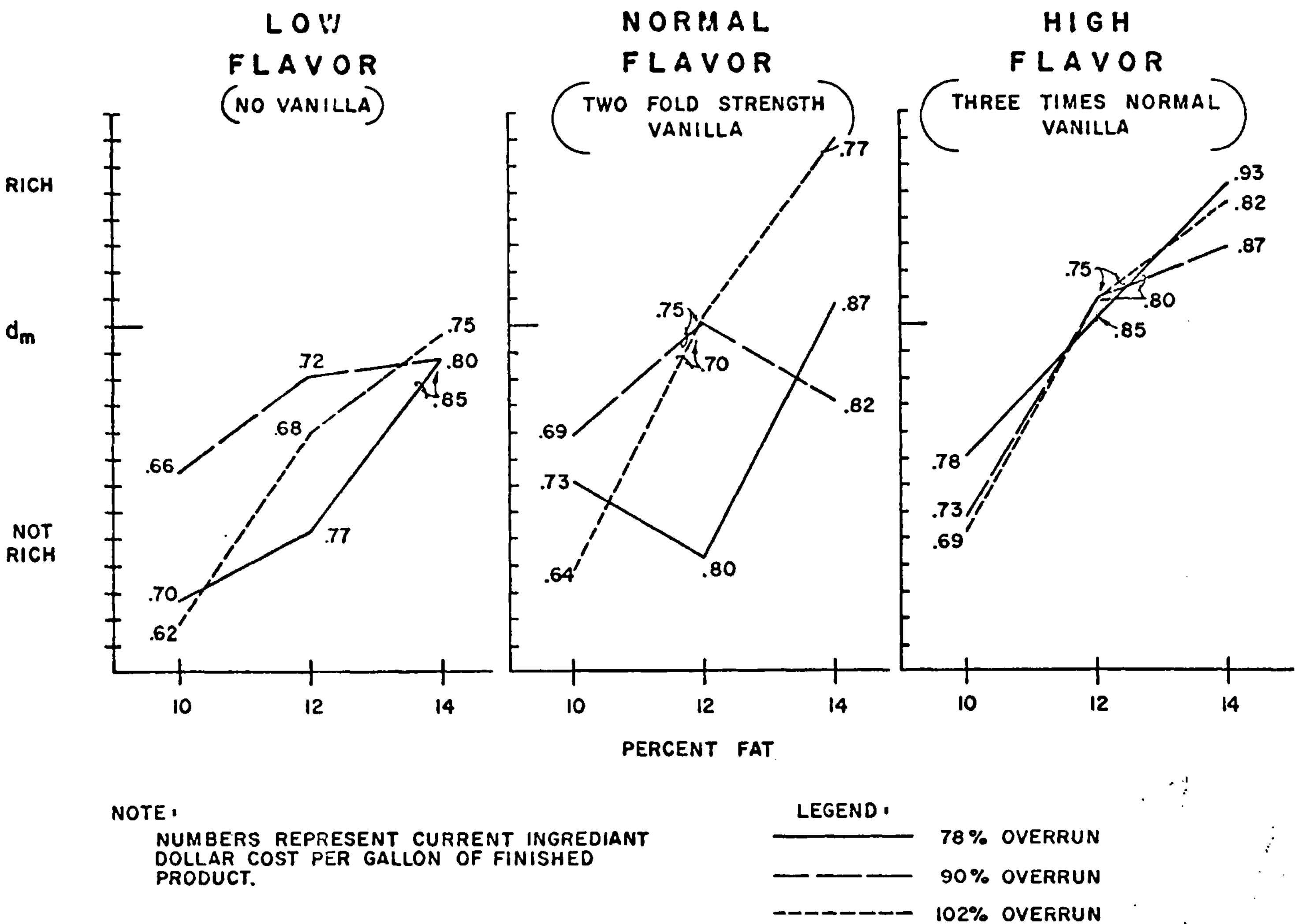

Figure 10. Current Cost for Each Mix and Its Relative Richness (d_m Value).

Conclusion

The evaluation of this experiment has shown that many assumptions and notions made for the purposes of the experiment were not correct. The problem may be traced to the confusion between preference and discrimination or more likely, preference and richness. Ice cream which is rich may not be preferred. The evaluation of the preference of ice cream, however, was not the goal of the TSD experiment. Determination of the test subjects' ability to discriminate fat levels was the primary goal. In the experiment, subjects were able to reliably discriminate two percent differences in ice cream mixes.

Employment of the rating scale method allowed not only the determination of discriminatory ability, but the determination of the richest tasting mix. The use of the TSD analysis eliminated the need to assume a homogeneous sample. Direct comparison of the TSD indices and the mean ratings indicated an insignificant amount of response bias, i.e., there was a high correlation between the two measures.

The scope of this experiment was not broad enough to determine the richest ice cream with respect to all possible dimensions of the mix. In terms of the three levels of fat, overrun, and flavoring, however, the results showed that the highest level of fat (14 percent), the highest level of overrun (102 percent), and the normal level of flavor constitutes a rich ice cream. The least cost combination of components with the best obtainable richness contained 10 percent fat, 90 percent overrun, and no vanilla flavoring. The implications of these results have important economic implications, since the higher level of overrun tends to require less mix per volume of ice cream.

CHAPTER 5

SUMMARY AND CONCLUSIONS

This study investigated the relationships between fat, overrun, and vanilla levels associated with preference and human discrimination ability for ice cream. The investigation also provided an opportunity to compare four experimental designs and their corresponding methods of statistical analysis. (The designs were paired comparison, triangle, Friedman chi square and TSD.) The findings of the study and suggestions for further study are summarized in this chapter.

The research reported in this thesis has not extensively evaluated the correlation between richness of an ice cream mix and the preference for that mix. It is reasonable to assume that richer mixes are preferred, but the preference results in Chapter 4 do not confirm that assumption. The medium fat mix was preferred by just as many subjects as the high fat concentration. The difference recorded in most cases was not statistically significant, which most likely resulted from the limited number of times each concentration was tested. Future studies of ice cream might consider the evaluation of preference with the very powerful TSD method.

Four statistical methods were utilized for the analysis of each experimental design. The research design dictated the type of analysis that could be properly applied. For instance, the previous research carried out by the Department of Dairy and Food Sciences contained data that could only be analyzed by a nonparametric statistical method. Since all the data was ranked in terms of preference, choice from an unknown distribution, it was necessary to employ the Friedman chi square statistical design where no assumption of a normal sampling distribution was necessary.

A cursory comparison of the different statistical methods would indicate differences in sensitivity and flexibility of each method. In experiments where systematic differences are likely to occur, the relatively simple paired comparison and triangle designs and their associated methods of analysis are well suited. They offer ease of analysis combined with a simple method of sampling. The results are easy to evaluate, and the entire experiment may be performed in a relatively short period of time. These designs, however, work well only when the samples represent rather large differences in content and the occurrence of individual response bias is not suspected. In addition, the number of experimental variables cannot be greater than one or two; otherwise, the sampling and analysis would be complicated far beyond the original advantage of the design. While the results of these simple tests are easy to interpret, the experimenter does not have any indication of the degree of difference recorded in the responses. Ranking the responses is certainly possible, but only at the expense of increased analytical complexity.

The TSD method achieves its greatest value when the occurrence of response bias is suspected to be present in the experiment. There are few experiments dealing directly with human subjects where response bias is not a subject of major concern. Heretofore, it has not been considered since few statistical methods were available to account for its presence. TSD, however, is a relatively complex experimental design and has prompted its followers to turn to computer analysis. In turn, the computer analysis allows the incorporation of additional variables with little increase in expense, but a great deal of increase in the amount of information received.

This research has shown that the human is able to distinguish two percent differences in fat level for vanilla ice cream. Discrimination ability has also been evaluated for overrun and vanilla flavoring. When determining discrimination ability, the degree of richness associated with three levels of fat, overrun, and vanilla was indicated. The amount of fat incorporated in ice cream tends to greatly influence the perceived richness experienced by the taster. The results of Chapter 4 affirmed that increased fat concentration produced a richer tasting product. The richer tasting product, however, is not entirely dependent on the fat concentration. Richness also depends upon the concentration of the other ingredients in the mix. A high fat mix, for example, with a medium to high overrun (90 to 102 percent) appears to be richer than a high fat in conjunction with a lower percentage overrun.

When the relative richness ranks of the different combinations of each mix were considered, the most interesting and richest mix came from the 14 percent fat in conjunction with the low density-high overrun (102 percent) mix. While this result is somewhat surprising, the conclusion is not at all unique. Over 60 years ago, a group of experimenters studied ice cream for fat with methods and analysis common for that period of time. Reported in the Vermont Agricultural Experiment Station bulletin (Bull. 155) in 1910, the researchers said (p. 32-33):

> It may seem strange to some that an experiment station should approve of the incorporation of air into ice cream. They may reason that the station advocates the dilution of the product, the selling of 'wind' as ice cream, a course quite as open to objection from the ethical, if not the legal standpoint as is the dilution of milk with water. Such a position, however, is untenable. It is a fact that an ice cream the volume which is approximately a third air is more satisfactory to the consumer than is one containing no air. It has a more velvety feel on the tongue, and conveys a sensation of richness without causing the unpleasant effects of an excessively rich cream, in the same way that a whipped cream or a well beaten egg seems richer than does the same article in its natural state. Furthermore, the presence of air in a finely divided form causes the whole mass to be in fact partially insulated against heat conduction, so that an ice cream containing air 'stands up' better both in the mouth and on the plate, than would the same cream if no air had been incorporated, and further, the whipped ice cream will chill the mouth and stomach of the consumer far less than that made without air. Neither is the presence of air a fraud on the consumer. Where six and one-half gallons of cream 'mix' is expanded into ten gallons of ice cream (54% swell) the product can, and because of competition will, be sold at a proportionately less price. The consumer will either get his ice cream for less money, or secure a larger dish for the same money. A demand that ice cream be served entirely devoid of air is no more reasonable than would be a requirement that a loaf of bread be held down to or compressed into the least possible volume. They both need to be light in order to attain the highest palatability.

APPENDIX A

SAMPLE FORMS

Sample Evaluation Questionnaire, Week 3

Department of Dairy and Food Sciences

Product Development and Test Marketing

EVALUATION QUESTIONNAIRE

Three samples of ice cream are presented for your consumer evaluation. These samples represent differences in formulation and composition. After testing each of the samples, indicate your evaluation on the basis of the preference rating indicated.

On the basis of no price difference, I rank the samples as follows:

Rank	Sample Color Code
First	Black
Second	Red
Third	Green

NAME______________________________

AGE_______________SEX______________

RESPONSE SCALE

9 - I am absolutely certain that the sample is rich.

8 - More than "fairly certain" -- rich.

7 - Fairly certain -- rich.

6 - More than "just guessing" -- rich.

5 - Just guessing -- rich.

4 - Just guessing -- not rich.

3 - More than just guessing -- not rich.

2 - Fairly certain -- not rich.

1 - More than "fairly certain" -- not rich.

0 - I am absolutely certain that the sample is not rich.

RESPONSES

1.___	21.___	41.___	61.___	81.___	101.___	121.___	141.___
2.___	22.___	42.___	62.___	82.___	102.___	122.___	142.___
3.___	23.___	43.___	63.___	83.___	103.___	123.___	143.___
4.___	24.___	44.___	64.___	84.___	104.___	124.___	144.___
5.___	25.___	45.___	65.___	85.___	105.___	125.___	145.___
6.___	26.___	46.___	66.___	86.___	106.___	126.___	146.___
7.___	27.___	47.___	67.___	87.___	107.___	127.___	147.___
8.___	28.___	48.___	68.___	88.___	108.___	128.___	148.___
9.___	29.___	49.___	69.___	89.___	109.___	129.___	149.___
10.___	30.___	50.___	70.___	90.___	110.___	130.___	150.___
11.___	31.___	51.___	71.___	91.___	111.___	131.___	
12.___	32.___	52.___	72.___	92.___	112.___	132.___	
13.___	33.___	53.___	73.___	93.___	113.___	133.___	
14.___	34.___	54.___	74.___	94.___	114.___	134.___	
15.___	35.___	55.___	75.___	95.___	115.___	135.___	
16.___	36.___	56.___	76.___	96.___	116.___	136.___	
17.___	37.___	57.___	77.___	97.___	117.___	137.___	
18.___	38.___	58.___	78.___	98.___	118.___	138.___	
19.___	39.___	59.___	79.___	99.___	119.___	139.___	
20.___	40.___	60.___	80.___	100.___	120.___	140.___	

DIFFERENCE/PREFERENCE TEST

Name________________________ Date______________ Product________________

1. Do you normally ___like, ___dislike this product: Check both if indifferent.

2. Compare the flavor of each of the numbered samples and indicate the relative difference and relative acceptance by checking the appropriate squares. DO NOT MARK BETWEEN SQUARES!

SAMPLE_________

Difference		Preference	
Great	4 /_/	More acceptable	/_/
Moderate	3 /_/		
Slight	2 /_/	Comparable	/_/
Very slight	1 /_/		
No difference	0 /_/	Less acceptable	/_/

Comments

____

____

____

SAMPLE_________

Difference		Preference	
Great	4 /_/	More acceptable	/_/
Moderate	3 /_/		
Slight	2 /_/	Comparable	/_/
Very slight	1 /_/		
No difference	0 /_/	Less acceptable	/_/

Comments

____

____

____

SAMPLE_________

Difference		Preference	
Great	4 /_/	More acceptable	/_/
Moderate	3 /_/		
Slight	2 /_/	Comparable	/_/
Very slight	1 /_/		
No difference	0 /_/	Less acceptable	/_/

Comments

____

____

____

Instructions

Ice cream composition standards are set by law. Ingredient combination variations within the legal frame are frequently based on management decision rather than on technical or scientific information. Actually there has been very little research to determine optimum combinations, for example, which affect the characteristic of richness.

The test in which you are about to participate is designed to give basic information about ice cream composition as it relates to richness. It is important to remember that the only correct response is your honest opinion.

The first two samples you will receive represent the extremes of richness in the ones to follow. From these two samples you will be able to judge the range in richness of those you will receive in the testing program. Your reaction to these samples is not to be recorded.

You will receive a small cup of ice cream about every minute. Disregard the number on the cup. Take a small spoonful. It is preferable to base your decision on your first impression and not by repeated testing. Make your reply on the answer sheet using one of the 10 numbers which represent certainty-of-response. These are on a card before you and will be explained momentarily. After sampling and recording your decision, please throw the sampled cup and its contents in the waste receptacle on the floor. Rinse your mouth with water when you want to.

Now, review the response chart in front of you. The numbers from 0 to 9 each indicate a specific certainty-of-response reaction. For example, nine means, "I am absolutely certain that the ice cream

Instructions

is rich." Seven means, "I am fairly certain that the ice cream is rich." Five means, "I'm just guessing, but the ice cream might be rich." Zero means, "I'm absolutely certain the ice cream is not rich."

In other words, we are asking you to put a numerical value on your own degree of certainty that each sample of ice cream is rich or not rich within the limits prescribed by the two reference samples. Please do your best in making judgments. After you have sampled a series of nine cups, you will have a five to ten minute rest period. There will be three series of nine samples each with rest periods between the first and second series. Please do not smoke or drink any liquid other than water during the rest periods. Water, cups and stainless steel waste containers are provided for your use during testing.

Sample Evaluation Questionnaire, Week 7

Department of Dairy and Food Sciences

Product Development and Test Marketing Project

EVALUATION QUESTIONNAIRE

You have received three samples of ice cream for preference evaluation. Three different fat contents are represented in the samples. These contents are either 10, 12, or 14 percent. The samples are randomly arranged and assigned code letters. After you have eaten or tested some of each sample, indicate your preference rating.

"On the basis of eating quality only, I rank the samples as follows:"

Rank	Code Letter of Sample
First	________
Second	________
Third	________

APPENDIX B

SUPPLEMENTARY DATA

d_m Values

LLL	-1.02579
MLL	- .77931
HLL	- .13180
LML	- .55716
MML	- .19712
HML	- .13157
LHL	-1.10882
MHL	- .39231
HHL	- .03762
LLM	- .59474
MLM	- .86599
HLM	+ .07188
LMM	- .42421
MMM	.00000
HMM	- .27762
LHM	- .92450
MHM	+ .00771
HHM	+ .68776
LLH	- .49945
MLH	+ .00128
HLH	+ .50486
LMH	- .73475
MMH	+ .08550
HMH	+ .27911
LHH	- .78797
MHH	+ .07522
HHH	+ .45938

FAT

L	10
M	12
H	14

OVERRUN

L	78
M	90
H	102

FLAVOR

L	None	0
M	Normal	-
H	High	+

Mean Rating Data

Fat-Overrun

Fat	78 Percent	90 Percent	102 Percent
10%	3.910	4.097	3.222
12%	4.222	5.583	5.271
14%	5.938	5.507	6.389

Overrun-Flavor

Overrun	L	M	H
78%	4.076	4.410	5.583
90%	4.938	4.979	5.271
102%	4.368	5.271	5.243

Mean Rating Order and Values

1	HHM	6.938
2	HLH	6.833
3	HHH	6.646
4	HMH	6.229
5	MMH	5.917
6	HLM	5.792
7	MLH	5.646
8	MMM	5.604
9	MHM	5.583
10	HHL	5.583
11	MHH	5.500
12	HML	5.375
13	MML	5.229
14	HLL	5.188
15	HMM	4.917
16	MHL	4.729
17	LMM	4.417
18	LLH	4.271
19	LML	4.208
20	LLM	4.063
21	LMH	3.667
22	MLL	3.646
23	LHH	3.583
24	LLL	3.396
25	MLM	3.375
26	LHM	3.292
27	LHL	2.792

Computed d_m Values for All Mixes

Fat (%)	OR (%)	Vanilla	No.	Cup No.	Code	d_m	
10	78	L	1	23	LLL	-1.02579	
		M	2	59	LLM	- .59474	$\bar{X}$-.69088
	L	H	3	4	LLH	- .49945	
L	90	L	4	11	LML	- .55716	
		M	5	1	LMM	- .42421	$\bar{X}$-.57204
	M	H	6	10	LMH	- .73475	
	102	L	7	3	LHL	-1.10882	
		M	8	20	LHM	- .92450	$\bar{X}$-.94043
	H	H	9	16	LHH	- .78797	
12	78	L	10	24	MLL	- .77931	
		M	11	18	MLM	- .86599	$\bar{X}$-.54801
	L	H	12	46	MLH	+ .00128	
M	90	L	13	8	MML	- .19712	
		M	14	17	MMM	.00000	$\bar{X}$-.037207
	M	H	15	22	MMH	+ .08550	
	102	L	16	15	MHL	- .39231	
		M	17	25	MHM	+ .00771	$\bar{X}$-.10313
	H	H	18	21	MHH	+ .07522	
14	78	L	19	5	HLL	- .13180	
		M	20	27	HLM	+ .07188	$\bar{X}$+.14031
	L	H	21	14	HLH	+ .50486	
H	90	L	22	12	HML	- .13157	
		M	23	26	HMM	- .27762	$\bar{X}$-.04336
	M	H	24	13	HMH	+ .27911	
	102	L	25	7	HHL	- .13180	
		M	26	2	HHM	+ .68776	$\bar{X}$+.03219
	H	H	27	19	HHH	+ .45938	

Mean Rating Data

Fat	10%	3.743	3.7
	12%	5.025	5.0
	14%	5.944	6.0
Overrun	78%	4.690	4.7
	90%	5.063	5.1
	102%	4.961	5.0
Flavor	L	4.461	4.5
	M	4.887	4.9
	H	5.366	5.4

Mean Ratings

Low Flavor

	78	90	102
10	3.4	4.2	2.8
12	3.7	5.3	4.7
14	5.2	5.4	5.6

Medium Flavor

10	4.1	4.4	3.3
12	3.4	5.6	5.6
14	5.8	4.9	6.9

High Flavor

10	4.3	3.7	3.6
12	5.7	5.9	5.5
14	6.8	6.3	6.7

APPENDIX C

COMPUTER PROGRAM FOR TSD ANALYSIS

```
      PROGRAM TSDXX(INPUT,OUTPUT,TAPE2=INPUT,TAPE3=OUTPUT,PUNCH,TAPE1)
C
      DIMENSION ID(500), A(500), B1(375,10), C(80)
      DIMENSION DPRIM(375), Z2(500,10), B2(10,375)
      COMMON JJJ,L1,L2,L3,L4,IJM
      COMMON L,JJ,R(500,10),B(100,10),PCOR(60),RCOR(60)
      REAL ID
C
C
      READ 59, IK
      DO 43 IKL=1,IK
      READ 50, (C(I),I=1,80)
      READ 59, JJJ,L,JJ,IJM,L1,L2,L3,L4
      KM=L-L/L1
      PUNCH 53
      P=L/L1
      Q=KM
      RN=JJJ
      DO 1 J=1,JJJ
      PCOR(J)=0.
1     RCOR(J)=0.
      DO 3 J=1,L
      A(J)=0.
      DO 2 K-1,JJ
2     R(J,K)=0.
3     CONTINUE
      DO 10 II=1,JJJ
      READ 44, (ID(J),J=1,L)
      DO 4 M=1,L
      LLL=ID(M)
      R(M,LLL+1)=R(M,LLL+1)+1.
4     CONTINUE
      DO 9 J=1,L1
      DO 9 I=J,L,L1
      LA=ID(I)+1.
C
C         FINDS THE NUMBER CORRECT
      IF (J-1) 6,6,5
5     GO TO (8,8,8,8,8,9,9,9,9,9), LA
6     GO TO (9,9,9,9,9,7,7,7,7,7), LA
7     PCOR(II)=PCOR(II)+(1./P)
      GO TO 9
8     RCOR(II)=RCOR(II)+(1./Q)
9     CONTINUE
10    CONTINUE
      CALL MEAN
      PRINT 52
      PRINT 47
C
C         THIS PRINTS OUT WHICH GROUP IS BEING ANALYZED.
```

```
      PRINT 50, (C(I),I=1,80)
C
C          PRINTS FREQUENCY TABLES
      PRINT 45
      CALL ONE
      CALL TWO
      DO 11 I=1,L
      DO 11 J=1,JJ
11    Z2(I,J)=R(I,J)
      DO 12 I=1,L
      DO 12 J=2,JJ
12    Z2(I,J)=Z2(I,J)+Z2(I,J-1)
C          CALCULATES TSD CUMULATIVE FREQUENCY TABLES.
      DO 14 N=1,L
      II=JJ
13    II=II-1
      R(N,II)=R(N,II+1)+R(N,II)
      IF (II-1) 14,14,13
14    CONTINUE
      PRINT 52
      PRINT 50, (C(I),I=1,80)
C
C          PRINTS CUMULATIVE FREQUENCY TABLES
      PRINT 51
      CALL ONE
      DO 16 I=1,L
      DO 16 J=1,JJ
C
C          CALCULATES CUMULATIVE PROBABILITY
      IF (R(I,J)-0.) 15,16,15
15    R(I,J)=R(I,J)/RN
16    CONTINUE
      PRINT 52
      PRINT 50, (C(I),I=1,80)
C
C          PRINTS CUMULATIVE PROBABILITY TABLES
      PRINT 48
      CALL ONE
C
C          CALCULATES Z SCORES FOR CUMULATIVE PROBABILITY
      DO 23 KK=1,L
      DO 23 LL=1,JJ
      IF (R(KK,LL)-1.) 17,18,18
17    IF (R(KK,LL)-1.) 19,19,20
18    R(KK,LL)=R(KK,LL)-.0062
      IF (R(KK,LL)-1.) 20,18,18
19    R(KK,LL)=R(KK,LL)+.0062
      IF (R(KK,LL)) 19,19,20
20    IF (R(KK,LL)-.5) 21,21,22
21    R(KK,LL)=1.-R(KK,LL)
```

```
      T=SORT(-2.*ALOG(1.-R(KK,LL)))
      R(KK,LL)=-(T-((2,30753+.27061*T)/(1.+.99229*T+.04481*
      (T**2))))
      GO TO 23
22    T=SORT(-2.*ALOG(1.-R(KK,LL)))
      R(KK,LL)=T-((2.30753+.27061*T)/(1.+.99229*T+.04481*(T**2)))
23    CONTINUE
      PRINT 52
      PRINT 50, (C(I),I=1,80)
C
C          PRINTS Z SCORE TABLES
      PRINT 49
      CALL ONE
      RJ=JJ-1
C
C          CALCULATES MEAN AND STANDARD DEVIATIONS FOR Z SCORES
      DO 26 MM=1,L
      ID(MM)=0.
      DO 24 NN=2,JJ
      ID(MM)=ID(MM)+R(MM,NN)/RJ
24    CONTINUE
      DO 25 IJ=2,JJ
      A(MM)=A(MM)+((R(MM,IJ)-ID(MM)**2)
25    CONTINUE
      A(MM)=SQRT(A(MM)/(RJ-1))
26    CONTINUE
      JI=0
      JK=2
      JL=L1
      DO 32 JM=1,L,L1
      DO 31 JN=JK,JL
      JI=JI+1
C
C          CALCULATES D PRIME
      IF (A(JM).EQ.0..OR.A(JN).EQ.0.) 27,28
27    T=0.
      GO TO 29
28    T=A(JM)/A(JN)
29    DPRIM(JI)=ID(JM)-(T*ID(JN))
      DO 30 KI=1,JJ
30    B1(JI,KI)=R(JM,KI)-R(JN,KI)
31    CONTINUE
      JL=JL+L1
      JK=JK+L1
32    CONTINUE
C
C     PRINTS TRADITIONAL CUMULATIVE FREQUENCY TABLES WITH COLLAPSINGS
C     FOR THE NUMBER OF VARIABLES INHERENT IN THE STIMULI.
C
      DO 33 I=1,L
      DO 33 J=1,JJ
```

```
 33       R(I,J)=Z2(I,J)
          PRINT 52
          PRINT 50, (C(I),I=1,80)
          PRINT 54
          CALL ONE
          CALL TWO
C
C              PRINTS D PRIME TABLES
          PRINT 52
          PRINT 50, (C(I),I=1,80)
          PRINT 56
          CALL THREE (DPRIM)
          JI=0
          JK=2
          JL=L1
          DO 38 JM=1,L,L1
          DO 37 JN=JK,JL
          JI=JI+1
C
C              CALCULATES DS
          IF (A(JM),EQ.O..OR.A(JN).EQ.O.) 34,35
          T=0.
          GO TO 36
 35       T=A(JM)/A(JN)
 36       DPRIM(JI)=(2.*DPRIM(JI))/(1.+T)
 37       CONTINUE
          JL=JL+L1
 38       JK=JK+L1
C
C              PRINTS DS TABLES
          PRINT 52
          PRINT 50, (C(I),I=1,80)
          PRINT 57
          CALL THREE (DPRIM)
          JI=0
          JK=2
          JL=L1
          DO 40 JM=1,L,L1
          DO 39 JN=JK,JL
          JI=JI+1
C
C              CALCULATES DM
 39       DPRIM(JI)=ID(JM)-ID(JN)
          JL=JL+L1
 40       JK=JK+L1
C
C              PRINTS DM TABLES
          PRINT 52
          PRINT 50, (C(I),I=1,80)
          PRINT 58
```

```
      CALL THREE (DPRIM)
      DO 41 I=1,KM
      DO 41 M=1,JJ
41    B2(M,I)=B1(I,M)
C
C     PRINTS AND PUNCHES DIS FOR USE IN ANOVA
      PRINT 52
      PRINT 50, (C(I),I=1,80)
      PRINT 46
      DO 42 I=2,JJ
      PRINT 55, (B2(I,M),M=1,KM)
      PRINT 47
      PUNCH 55, (B2(I,M),M=1,KM)
42    CONTINUE
43    CONTINUE
      STOP
C
44    FORMAT (40F2.0)
 45   FORMAT (30X,*FREQUENCY TABLES*,/)
 46   FORMAT (30X,*DATA TO BE ANALYZED BY ANOVA*,/)
47    FORMAT (/)
 48   FORMAT (30X,*CUMULATIVE PROBABILITY TABLES*,/)
 49   FORMAT (30X,*Z SCORE TABLES*,/)
50    FORMAT (80R1)
 51   FORMAT (30X,*CUMULATIVE FREQUENCY TABLES*,/)
52    FORMAT (1H1)
53    FORMAT (*+++++++++++++++++++++++++++++++++++++++++++++++++++++++++*)
 54   FORMAT (20X,*TRADITIONAL CUMULATIVE FREQUENCY TABLES*,/)
55    FORMAT (10F8.4)
 56   FORMAT (30X,*D PRIME TABLES*,/)
 57   FORMAT (30X,*DS TABLES*,/)
 58   FORMAT (30X,*DM TABLES*,/)
59    FORMAT (10I5)
      END
      SUBROUTINE ONE
C
C          THIS ROUTINE PRINTS OUT FREQUENCY, CUMULATIVE FREQUENCY,
C          CUMULATIVE PROBABILITY, AND Z SCORE TABLES CALCULATED IN
C          MAIN PROGRAM.
C
      COMMON JJJ,L1,L2,L3,L4,IJM
      COMMON L,JJ,R(500,10),B(100,10),PCOR(60)
      DO 2 I=1,L,L1
      LL=I+(L1-1)
      J1=-1
      DO 1 J-1,JJ
      J1=J1+1
      PRINT 3, J1,(R(K,J),K=I,LL)
1     CONTINUE
      PRINT 4
2     CONTINUE
```

```
      PRINT 4
      PRINT 4
      RETURN
C
3     FORMAT (3X,I4,1X,11F11.5)
4     FORMAT (/)
      END
      SUBROUTINE TWO
C
C          THIS ROUTINE COLLAPSES AND PRINTS FREQUENCY TABLES AND
C          TRADITIONAL CUMULATIVE FREQUENCY TABLES BY THE MAIN
C          SIGNAL/NOISE VARIABLE (L1) AND, IN ORDER, EACH OF THE
C          SUBSEQUENT VARIABLES IN THE EXPERIMENT.
C
      COMMON JJJ,L1,L2,L3,L4,IJM
      COMMON L,JJ,R(500,10),B(100,10),PCOR(60)
      DO 20 K=1,IJM
      DO 1 I=1,100
      DO 1 J=1,JJ
1     B(I,J)=0.
      PRINT 24
      PRINT 21, K
      PRINT 23
      IF (K-2) 3,4,2
2     IF (K-4) 5,6,6
3     MM=L1
      GO TO 7
4     MM=L1*L2
      GO TO 7
5     MN=L1*L2*L4
      MM=L1*L3
      M=1+L1
      N=MM
      GO TO 9
6     M=1
      MN=L1*L2*L3
      MM=L1*L4
      N=MN
      GO TO 14
7     DO 8 I=1,MM
      DO 8 J=I,L,MM
      DO 8 KK=1,JJ
8     B(I,KK)=B(I,KK)+R(J,KK)
      GO TO 17
9     DO 10 J=1,MN
      DO 10 I=J,L,MN
      DO 10 KK=1,JJ
10    B(J,KK)=B)J,KK)+R(I,KK)
      DO 13 I=1,MM,L1
      DO 12 JK=1,L1
      DO 11 J=M,M,L1
```

```
      DO 11 KK=1,JJ
      IK=JK-1
11    B(I+IK,KK)=B(I+IK,KK)+B(J,KK)
      M=M,1
12    CONTINUE
      M=M=L1+MM
      N=N+MM
13    CONTINUE
      GO TO 17
14    DO 16 I=1,MM,L1
      DO 15 J=M,N,L1
      DO 15 KK=1,JJ
      DO 15 LMN=1,L1
      IK=LMN-1
15    B(I+IK,KK)=B(I+IK,KK)+R(J+IK,KK)
      M=M,MN
      N=N+MN
16    CONTINUE
17    DO 19 I=1,MM,L1
      J=I+(L1-1)
      J1=-1
18    PRINT 22, J1,(B(M,KK),M=I,J)
      PRINT 23
19    CONTINUE
      PRINT 23
      PRINT 23
20    CONTINUE
      RETURN
C
 21   FORMAT (18X,*MATRIX REPRESENTING INTERACTION OF VARIABLE(S) 1
     AND*1,I2,/)
22    FORMAT (3X,I4,1X,11F11.5)
23    FORMAT (/)
24    FORMAT (1H1)
      END
      SUBROUTINE THREE (A1)
C
C          THIS SUBROUTINE PRINTS TABLES FOR D PRIME, DS, AND DM.
      DIMENSION A1(375)
      COMMON JJJ,L1,L2,L3,L4,IJM
      COMMON L,JJ,R(500,10),B(100,10),PCOR(60)
      IKN=L1-1
      KM=L-L/L1
      DO 1 I=1,KM,IKN
      PRINT 3
      LL=I+(IKN-1)
1     PRINT 2, (A1(J),J=I,LL)
      PRINT 3
      PRINT 3
      RETURN
C
```

```
2       FORMAT (8X,11F11.5)
3       FORMAT (/)
        END
        SUBROUTINE MEAN
C           THIS ROUTINE CALCULATES AND PRINTS SUBJECT MEANS FOR
C           SIGNAL AND NOISE CONDITIONS SEPARATELY, GRAND MEANS
C           COMBINED ACROSS ALL SUBJECTS AND THE STANDARD DEVIATION
C           FOR THE GRAND MEANS.
        COMMON JJJ,L1,L2,L3,L4,IJM
        COMMON L,JJ,R(500,10),B(100,10),PCOR(60),RCOR(60)
        RN=JJJ
        PSD=0.
        RSD=PSD
        PCTOT=PSD
        RCTOT=PSD
        DO 1 J=1,JJJ
        PCTOT=PCTOT+PCOR(J)/RN
1       RCTOT=RCTOT+RCOR(J)/RN
        DO 2 J=1,JJJ
        PSD=PSD+((PCOR(J)-PCTOT)+(PCOR(J)-PCTOT))/RN
2       RSD=RSD+((RCOR(J)-RCTOT)*(RCOR(J)-RCTOT))/RN
        PSD=SQRT(PSD)
        RSD=SQRT(RSD)
        PRINT 7
        PRINT 5
        DO 3 J=1,JJJ
        PRINT 11
        PRINT 9, J,PCOR(J)
        PRINT 10
        PRINT 9, J,RCOR(J)
3       PRINT 4
        PRINT 6
        PRINT 11
        PRINT 9, JJJ,PCTOT
        PRINT 10
        PRINT 9, JJJ,RCTOT
        PRINT 4
        PRINT 8
        PRINT 11
        PRINT 9, JJJ,PSD
        PRINT 10
        PRINT 9, JJJ,RSD
        RETURN
C
4       FORMAT (/)
 5      FORMAT (30X,*SUBJECT MEANS*,/)
 6      FORMAT (30X,*GRAND MEANS*,/)
7       FORMAT (1H1)
 8      FORMAT (30X,*STANDARD DEVIATIONS*,/)
9       FORMAT (30X.I3.F14.5)
```

```
10      FORMAT (30X,*NOISE*)
11      FORMAT (30X,*SIGNAL*)
        END
```

REFERENCES

American Society for Testing and Materials, Manual on Sensory Testing Methods, Technical Publication No. 434, Baltimore, Md., 1968.

Arizona Revised Statutes Annotated, ARS 3-625B, 1956, Volume 2, p. 349, West Publishing Co., St. Paul, Minnesota, 1956.

Bradley, James V, Distribution-Free Statistical Tests, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, p. 126.

Byer, Albert J. and Dorothy Abrams, "A Comparison of the Triangle and Two-Sample Taste-Test Methods," Journal of Food Technology, No. 7, 1953, pp. 185-187.

Consumer Reports, "Ice Cream," Consumers Union of United States, Inc., Mount Vernon, New York, August 1972.

Daniel, Terry C., Lawrence Wheeler, Ronald S. Boster and Paul R. Best, Jr., Quantitative Evaluation of Landscapes: A Preliminary Application of Signal Detection Analyses to Selected Forest Management Alternatives, unpublished manuscript, 1972.

Friedman, Milton, "The Use of Ranks to Avoid the Assumption of Normality Implicit in the Analysis of Variance," Journal of the American Statistical Association, Vol. 32, 1937, pp. 675-679.

Keeney, Mark, "The Field of Butterfat Research," International Association of Ice Cream Manufacturers and Milk Industry Foundation, Boston, Massachusetts, 1953, p. 31.

Merck, An Introduction to Taste Testing of Foods, Chemical Division Technical Bulletin, Merck & Co., Inc., Rawway, New Jersey, 1963.

Miller, Rupert G., Simultaneous Statistical Inference, McGraw-Hill Book Company, New York, 1968.

Siegel, Sidney, Nonparametric Statistics for the Behavioral Sciences, McGraw-Hill Book Company, New York, 1956.

Steel, Robert G. D. and James H. Torrie, Principles and Procedures of Statistics, McGraw-Hill Book Company, Inc., New York, 1960.

Tracy, P. H., "A Study of Ice Cream Types," International Association of Ice Cream Manufacturers, Dallas, Texas, October 18-20, 1937, pp. 60-72.

Vermont Agricultural Experiment Station, Bulletin 155, University of Vermont, 1910.

Wheeler, L., T. Daniel, G. Seeley and W. Swindell, "Detectability of Degraded Visual Signals: A Basis for Evaluating Image-Retrieval Programs," Optical Sciences Center Technical Report 72, University of Arizona, 1971.

Williams, Owen E. and George R. Campbell, "Effect of Composition on the Palatability of Ice Cream," United States Department of Agriculture, Bulletin No. 1161, Washington, D. C., 1923, pp. 3-7.

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