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LINEAR PROGRAMMING
AND CONSUMERS' IDEAL SENSORY ATTRIBUTES
IN PRODUCT OPTIMIZATION

A Thesis
presented in partial fulfilment of
the requirements for the degree of
Master of Technology in Product Development
at Massey University

HATHAIRAT UAPHITHAK

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ABSTRACT

Sensory attribute/ingredient relationships and consumers' ideal product profile were used to develop constraints for linear programming in hand cream optimization using rice bran oil to replace mineral oil. At the beginning of the process, consumer testing was conducted in order to elicit the important attributes of the product as perceived by the consumers. Simultaneously, the strengths and weaknesses of hand creams on the market were identified, and an ideal product profile developed for hand creams.

A fractional factorial design, 2^{6-2}, was used to identify the main effects of the ingredients on the product attributes. A quantitative sensory profile technique and a trained sensory panel were employed in the product sensory evaluation of the samples. The mean scores of each sensory attribute were regressed against the levels of the ingredients in the formulations. Only the main effects of the ingredients were identified according to the design of the experiment. Most sensory attributes, consistency, spreadability, oiliness, shine and stickiness, had significant linear relationships with the ingredients. Moistness, softness and absorbability did not.

The linear relationships were then used to develop sensory constraints for the linear programming model. Upper and lower limits of these constraints were set from the consumers' ideal product profile, by adding and subtracting 1 from the ideal attribute levels. Other constraints were on ingredient levels based on formulation needs. LP88 computer program was used to solve this hand cream problem, the objective being minimum cost.

A hand cream was made using the optimum formulation from the linear programming and tested with the trained sensory panel. Ideal ratio scores (i.e. ratio of the sample mean score to the ideal score) of this hand cream's

attributes were not more than 0.3 away from the ideal. The product was then tested with a consumer panel of 20 hand cream users. In consumer testing, the optimum product was tested along with the leading commercial products in order to compare consumer acceptability on these products and to test if the optimum product could compete with the products already in the market. The results showed the consumers preferred the optimum product to the commercial products and the optimum product was closer to the ideal.

From the linear programming model used in this study, the attribute levels of the hand cream can be modified by adjusting the constraints and studies can be made of the effect of changes in ingredients on product attributes.

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CHAPTER 1

INTRODUCTION

Product optimization is one of the important stages in product development. It is defined as a comprehensive and efficient approach which develops a product highly acceptable to the consumer, in a short time, while minimizing the cost.

The goal of optimization is to maximize consumer acceptance of a product, from a fixed number of ingredients, and the outcome of the process should support key decisions evolving from company policy and strategy. Hence, a product optimization method will consider all these constraints and objectives, and will help the product developer to select formulation alternatives. When new products are developed, another goal of the optimization procedure is to provide the product developer with information regarding the effects of input variables on the output variables of the finished products. Thus, it is necessary to develop empirical equations that relate output to input variables for optimization process.

1.1 OPTIMIZATION PROCEDURE

Several optimization methods have been developed by many researchers (Fishken, 1983; Sidel and Stone, 1983; Giovani, 1983; Schutz, 1983; and Moskowitz, 1983 and 1987). Although these methods differ, they include:

* An initial development study in which prototypes are developed; critical input variables are identified during this stage.

* A screening product formulation development step which

includes the determination of the levels (or range) of ingredients and processing variables for the subsequent optimization study. Some authors conduct sensory evaluation tests at this stage.

* A formal optimization study, with or without constraints, that includes consumer testing, data analysis, reformulation, and implementation.

1.2 AN INITIAL DEVELOPMENT STAGE

1.2.1 Find Information about Existing Products

The product developer has to find information about the strengths and weaknesses of competitors, and about changing costs of goods, then makes a decision about what to launch and how to support the product. It is important to understand the situation of the market place before making decisions regarding products. Product developers should always evaluate their own products against the single leading market competitor.

In order to measure consumer reactions to competing products in the market, it is important to obtain a comparative profile of the different products in the marketplace on a series of different product attributes (Moskowitz and Rabino, 1983). By comparing products on this profile it becomes possible to determine quickly which products perform well on which specific attributes.

1.2.2 Product Design Specification

After obtaining enough information about the product to be developed, the product developer has to develop a product design specification to get the clear description about the product. This is to interpret consumer needs or wants into technical terms. A great deal of further information is needed to change the product idea concept into a product design specification including; raw materials, processing, product quality and target market.

1.2.3 Identifying the Variables

The variables are divided into input variables and output variables. For example, in hand cream products input variables are ingredients and output variables are physical and sensory attributes. In studying the variables in a product development process, the product developer has to firstly identify all the variables, then decide which are the most important variables.

It is important to limit the number of variables to be studied but choosing too few variables can limit the usefulness of the experiment. The important variables can often be determined from past experiments, from study of the literature, and from consumer research.

1.3 SCREENING PRODUCT FORMULATION DEVELOPMENT

From the initial development stage, the product developer obtains the direction of the target product. Now the decision has to be made on what prototype(s) should be developed.

Experimenters design experiments in order to answer specific questions and to build a mathematical model. The choice of a specific experimental design will depend upon the project's objectives. An experimental design should be straightforward to plan and execute and simple to analyze.

Traditionally back-and-forth techniques for testing and reformulation of products have been used. Those procedures could require months and were substantially more expensive than an optimization method which reduces the trial and error experiments (Moskowitz, 1983). Giovanni (1983) also stated that these approaches are insufficient for three reasons. Firstly, a large number of experiments is required, which can be expensive and time consuming. Secondly, the optimum product might not be determined by these approaches because the experimenter must use educated guesses to specify the levels of the various ingredients to test. Thirdly, this approach does not establish an equation which describes the relationship between the input decision variables and output responses to these variables.

Most researchers agree that a multi-product procedure is more efficient than the traditional method of back-and-forth testing. The multi-product approach, which is common to most optimization methods, tests many prototypes and develops a model relating decision variables and objective measures. The process requires one to two cycles, and takes about 3 months (Moskowitz, 1983).

Experimental designs have been successfully used in product optimization planning to select a subset of all possible samples which could be tested. While covering the range of factor levels specified in the experiment, the experimental design emphasizes those samples closest to the midpoints of these ranges, thereby decreasing the total number of samples which must be tested (Giovanni, 1983).

Factorial designs, mixture designs and central composite designs are used by many product developers to optimize product formulation.

1.4 OPTIMIZATION

Optimization of a product can be considered in terms of the analogy of 'hill climbing' (Charalambous, 1984). By envisioning the product models as a 'hill', one must find the top of the hill to optimize a product.

To obtain the relationship between input variables and output variables, the data from the previous stage have to be analyzed. Data interpretation is naturally an important step of the optimization process. The experimenter must choose the method of analysis before starting the research because the choice of an experimental design depends upon the type of analysis conducted on the data.

Moskowitz (1987) used multiple regression analysis to develop equations relate sensory characteristics and input variables, as well as an equation relating consumer acceptance to ingredient levels. From these equations the values for the optimum product were substituted and consumer reaction to the product could be estimated. In this method it is possible to minimize cost of the product and maximize overall acceptance at the same time by using the computational algorithm as follows:

* Try a new formula level obtained from the equations.

* Establish whether the new trial formula generates an increased level of acceptance. If it does not, go back to a new trial formula before proceeding. If the new formula does achieve a higher acceptance level, continue.

* Check the costs of the new formula. (If the cost of goods exceeds the maximum, then go back and try a new formula).

This method is not straightforward and the product developer has to try several combinations until the optimal product is obtained.

Linear programming is another important method which has been successfully used in product optimization by several researchers (Kavanagh, 1978; Chan and Kavanagh, 1988; Beausire et al., 1988). Linear programming, a mathematical optimization technique, is used in both the food and non-food industries for resource allocation and product formulation problem solving. Linear programming was used in paint and resin formulation (Kavanagh, 1978) and light duty liquid detergent formulation (Chan and Kavanagh, 1988) in order to obtain a good, low cost formulation, which matched or exceeded the properties of a commercially available product, in a small number of experiments. In this method, a formulation of various components which the formulator, based on experience and knowledge, believed would meet the required specifications was produced and tested. Successive uses of multiple regression analysis and linear programming were applied at each step to obtain a formulation which met the required specifications at the lowest cost. If the tests showed that the formulation did not meet the required specifications, then the formulator adjusted the quantities of the components, added or deleted components to try to obtain a formulation which did meet the specifications.

Whereas the optimal formulation can be obtained in a small number of experiments from this method, formulator experience and knowledge are needed in choosing the input variables for the linear regression. Hence, it is not appropriate if the formulator has no experience about the product.

The sensory properties of a product are very important factors in a formulation problem. In linear programming optimization, sensory properties have been constrained by a combination of ingredient limits (upper and lower bounds), and the development of constraints based on quantitative models of functional properties of the ingredients (Hsu, et al., 1979). The studies by many researchers failed to take into account the relationship between the sensory properties and the consumer acceptance of the product.

Beausire et al. (1988) used linear programming in fresh turkey bratwurst formulation. In their study, an experimental design and in-house sensory panel determined quantitative relationships between the product's textural attributes and the ingredients. Then the product toughness/ingredients relationship was utilized to develop three formulations with different levels of toughness. These formulations were market tested using the acceptor set size as the measure of market acceptability. A relationship between product toughness and acceptor set size was determined, into which was substituted the toughness/ingredient relationship. This model was added to the least cost linear programming model in the form of an acceptability constraint.

Although this method included acceptability constraints into the linear programming, it may not be possible to obtain a product which contains the acceptable levels for the important attributes, since only one sensory attribute is studied. Also in obtaining the model showing the relationship between the sensory attribute and acceptability only three samples were used to get the linear equation; this equation may not have represented the actual relationship.

1.5 USING OPTIMIZATION PROCEDURES IN FORMULATION OF A NEW HAND CREAM PRODUCT.

Consumers have now become aware of safety in product use, and they tend to prefer natural products which are produced from natural raw materials and which do not cause any side-effects.

Mineral oil is used as emolient in most hand creams. Its occlusive action aids in rehydration of the corneum when allowed to remain on the skin for an appreciable length of time. Because the solvent action of mineral oil tends to remove skin surface lipids when the cream is applied for a short period of time, partial replacement with a vegetable oil is needed (Grayson and Eckroth, 1979). It has also been found that mineral oils are a carcinogenic risk to humans (Haas et al., 1987). Hence, vegetable oils have the potential to be used instead of mineral oil in skin care products.

Rice bran oil is obtained from rice bran by conventional expression and solvent extraction techniques using a variety of solvents such as hexane, and ether. The composition of rice bran oil suggests its use as a salad and cooking oil, and for making hydrogenated shortening (Bailey, 1964) . It has also been used as a leather tanning oil (replacing sperm oil), as a textile lubricant by textile mills to keep yarn from fibrillating, and as a rust inhibitor.

Rice bran oil has been used in cosmetic products especially skin care products: soap, bath oils and hand creams.It has been used in a sun screen product (Loo, 1976). It is non-toxic and non-irritating to the skin of all subjects tested, does not discolour, develop odour or otherwise deteriorate upon exposure to sunlight, so it is suitable to use in skin care products. Since rice bran oil contains natural antioxidants (tocopherols), it is not necessary to add any antioxidant in the product.

As rice is one of the major cereal crops in the world, there are several rice bran oil extracting factories; and now there are rice companies in many countries, such as U.S.A., India and Thailand, considering oil extraction so there will be plenty of rice bran oil available to be used. Production of formulated products using rice bran oil in cosmetics is also one way of value adding to this raw material.

In this study, an optimization procedure was used to develop a natural hand cream product. The product concept required the development of a hand cream using rice bran oil as a substitute for mineral oil.

Consumer testing was used to gain consumers' perception of the products already on the market. Important attributes were identified to guide the formulator in developing a product which contained acceptable levels of these attributes. After the experimental study, multiple regression was used to generate linear relationships between input variables and sensory attributes, then consumer acceptance was maximized by inputting the sensory constraints in the linear programming model. The upper and lower bounds of the constraints were obtained from the consumers' ideal attributes.

1.6 AIM OF THE PROJECT

The aim of this project was to use consumers' ideal attributes and multiple regression to develop sensory constraints for a linear programming model in product formulation.

1.6.1 Objectives

* To set up a consumers' ideal product profile for hand cream products.

* To obtain empirical equations showed relationships between input variables (raw materials) and sensory attributes.

* To use the empirical equations in linear programming to formulate a hand cream product.

* To evaluate a prototype hand cream from linear programming with a trained panel and consumer panel.

* To obtain an optimal product which is accepted by the consumers.

1.6.2 Constraints

1.6.2.1 Product constraints

* The product should be formulated by using vegetable oil (rice bran oil) instead of mineral oil.

* The product should have sensory attributes which is accepted by the consumer and can compete with the products in the marketplace.

1.6.2.2 Processing constraints

* Only known technology is to be used and new processing techniques are not to be investigated.

* Commercially available raw materials are to be used as much as possible.

CHAPTER 2

REVIEW OF USING LINEAR PROGRAMMING IN PRODUCT OPTIMIZATION

2.1 INTRODUCTION

Programming problems are concerned with the efficient use or allocation of limited resources to meet desired objectives. Those problems are characterized by the large number of solutions that satisfy the basic conditions of each problem. The selection of a particular solution as the best solution to a problem depends on some aim or over-all objective that is implied in the statement of the problem. A solution that satisfies both the conditions of the problem and the given objective is termed an optimum solution (Gass, 1975).

A linear programming problem differs from the general variety in that a mathematical model or description of the problem can be stated, using relationships which are called 'straight-line', or linear. Mathematically, these relationships are of the form:

$$a_1x_1 + a_2x_2 + \ldots + a_jx_j + \ldots + a_nx_n = b$$

where a_j's and b are known coefficients and x_j's are unknown quantities of the variables. The complete mathematical statement of a linear programming problem includes a set of simultaneous linear equations which represent the conditions of the problem.

Linear programming was first introduced by Dantzig in 1947 to aid military planning. Since that time, many applications have been developed. Some of the more common are economic analysis and the solution of production, sales, inventory and transportation problems.

2.2 THE STRUCTURE OF LINEAR PROGRAMMING PROBLEMS IN FORMULATION

Linear programming problems are characterized by the following framework:

2.2.1 Objective Function

This is the measuring device used to compare alternatives. Typically, these measures are economic in character, i.e., profit maximization or cost minimization in producing a hand cream product.

2.2.2 Decision Variables

These are the amounts of input variables which have to be determined and can specify any of the alternative formulations. In the hand cream problem, the ingredient amounts are decision variables since they define the solution.

2.2.3 Constraints

These are the restrictions placed on the formulation. Typical restrictions are imposed by the manufacturers, by the technology, or by the government. In the hand cream problem, the target levels of sensory attributes restrict the amounts and kinds of inputs chosen in the formulation. It can be said that, the constraints restrict the values of the decision variables in the optimal solution. An alternative which satisfies all the constraints is called 'feasible'.

2.3 THE GENERAL LINEAR PROGRAMMING MODEL

Linear programming problems involving two variables are written as the following model:

maximize or minimize

$$z = c_1x_1 + c_2x_2 \qquad (2.3.1)$$

subject to

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 &\ (\leq)(\geq)(=)\ b_1 \\ a_{21}x_1 + a_{22}x_2 &\ (\leq)(\geq)(=)\ b_2 \\ &\vdots \\ a_{m1}x_1 + a_{m2}x_2 &\ (\leq)(\geq)(=)\ b_m \end{aligned} \qquad (2.3.2)$$

and

$$x_1 \geq 0,\ x_2 \geq 0 \qquad (2.3.3)$$

In each of the m equations of (2.3.2), any one of the symbols $\leq$, $\geq$, $=$ may be used.

The above model is the general linear programming problem with two variables. Equation (2.3.1) is called the 'objective function'. Equations (2.3.2) and (2.3.3) are called the 'constraints'; in particular, Equations (2.3.3) are called the 'nonnegativity constraints' on the variables x_1 and x_2.

A pair of values (x_1, x_2) which satisfy all of the constraints is called a 'feasible solution'. The set of all feasible solutions determines a subset of the x_1x_2-plane called the 'feasible region'. The feasible solution which maximizes (or minimizes) the objective function is called an 'optimal solution'.

To examine the feasible region of a linear programming problem, it is necessary to note that each constraint of the form

$$a_{i1}x_1 + a_{i2}x_2 = b_i$$

defines a line in the x_1x_2 -plane, while each constraint of the form

$$a_{i1}x_1 + a_{i2}x_2 \leq b_i$$

or

$$a_{i1}x_1 + a_{i2}x_2 \geq b_i$$

defines a half-plane which includes its boundary line

$$a_{i1}x_1 + a_{i2}x_2 = b_i$$

Thus, the feasible region is always an intersection of many lines and half-planes. If the feasible region can be enclosed in a sufficiently large circle, it is called 'bounded'; otherwise it is called 'unbounded'. If the feasible region is 'empty' (contains no points) then the constraints are inconsistent and the linear programming problem has no solution. Those boundary points of a feasible region which are intersections of two of the straight line boundary segments are called 'extreme points'. They are also called 'corner points' or 'vertex points'.

Linear programming problems involving two variables can be effectively solved by a graphical approach (see Rorres and Anton, 1979 for details). Bender and Kramer (1983) and Edwardson et al. (1985) have also given examples of graphic solutions of linear programming problems.

The graphical method, although useful for solving linear programming problems in two variables, is not practical for the solution of linear programming problems in three or more variables.

The Simplex is an algorithm developed by Dantzig (1967) to solve linear programming problems in any number of variables. It can be viewed as a simplex searches from one corner to the next until an optimal solution is found (Bender and Kramer, 1983).

The 'general linear programming model in n variables', can best be summarised by the following equations:

maximize or minimize

$$z = c_1x_1 + c_2x_2 + \dots + c_nx_n \qquad (2.3.4)$$

subject to

$$a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n \ (\leq)(\geq)(=) \ b_1$$

$$a_{21}x_1 + a_{22}x_2 + \dots + a_{2n}x_n \ (\leq)(\geq)(=) \ b_2 \qquad (2.3.5)$$

$$\vdots$$

$$a_{m1}x_1 + a_{m2}x_2 + \dots + a_{mn}x_n \ (\leq)(\geq)(=) \ b_m$$

and

$$x_i \geq 0, \text{ for } i = 1, 2, \dots, n. \qquad (2.3.6)$$

The linear function z in (2.3.4) is called the 'objective function' and conditions (2.3.5) and (2.3.6) are called the 'constraints' of the problem (Rorres and Anton, 1979). $c_1, \dots, c_n$ are the costs of the variables $x_1, \dots, x_n$ and $a_{11}, \dots, a_{mn}$ are constants of the variables $x_1, \dots, x_n$. The problem is to find values of $x_1, \dots, x_n$ which will satisfy the constraints $b_1, \dots, b_m$ and at the same time minimize the total cost, z.

In this study, $x_1, \dots, x_n$ were the amounts of various components, such as rice bran oil, mineral oil, glyceryl monostearate, etc. in the formulation. The cost per unit of these components are $c_1, \dots, c_n$. The constraint equations would represent various properties that the final formulation must have. For example, the consistency must be equal to, or greater than, a value selected by the formulator. This selected value can be in any units, even the units of an arbitrary scale from 0 to 15. The linear programming would give the amount of each component in the formulation required to give the desired properties at minimum cost. Details of simplex method have been given by Rorres and Anton (1979).

2.4 APPLICATION OF LINEAR PROGRAMMING IN PRODUCT OPTIMIZATION

Product formulation of a multicomponent system is not an easy task for a formulator. In general, the formulator will select from a number of components to be mixed or reacted to obtain a formulation which matches or exceeds one or more of the required properties or specifications. Minimum cost is also required. The formulator, based on his/her experience and knowledge of the formulation, can use trial and error methods or the one factor-at-a-time method to obtain a formulation which will match all the required specifications. Statistical methods are developed to handle this problem in a logical manner. Experimental designs and regression analysis can be used to find how the product properties are related to the components of the multicomponent system of the product formulation. Thereafter, an optimization technique is used to obtain the optimal formulation of the system.

Linear programming has been used successfully in the formulation of luncheon meat and sausage products (Nicklin, 1979; Skinner and Debling, 1969), low cholesterol-low fat stew and mayonnaise (Bender, Kramer and Kahan, 1976 and 1982) and beer and ice-cream (Danø, 1974).

2.4.1 Meat Products

The formulation of meat products is a problem which the food industry has commonly solved by using linear programming. Rust (1976, cited in

Norback and Evans, 1983) used linear programming in formulating preblended meats. This method was also used in formulating luncheon or sandwich meat (IBM, 1966; Wieske, 1982), and a protein enriched luncheon sausage (Nicklin, 1979). In each of these formulation problems, the objective was to minimize cost when given a set of constraints on the formulation and on the availability of inputs.

2.4.2 Ice Cream

Another food product which has been successfully formulated in industry using linear programming is ice cream (Danø, 1974). A detailed example in the Danø (1974) reference illustrates the value of linear programming in finding the optimal formulation of ice cream from an large number of various input variables.

2.4.3 English style crumpets

Smith et al. (1984) reformulated crumpets to a desired water activity (a_w) by the use of a linear programming technique. Constraints were placed on batch size, moisture, carbohydrate, protein and fat content of the product. An additional constraint was placed on a_w (0.97-0.955) whereby each ingredient was calculated in terms of its sucrose equivalent on which its contribution to product a_w was based. The experiment demonstrated the merits of linear programming in reformulation studies and shelf-life extension of a bakery product.

2.4.4 Processed Cheese Products

Craig et al. (1989) used a linear programming model to integrate cheese manufacturing, blending and aging and flavour components for a processed cheese manufacturing operation. The input resources for the processed cheese product were identified and defined. The constraints defined the desired product using legal, quality, and management guidelines. The objective function maximized the net returns of a pasteurized processed cheese batch.

2.4.5 Paint and Resin

Linear programming was applied to paint and resin formulation by Kavanagh (1978). An acrylic automobile lacquer was developed to equal or exceed the properties of a commercially available lacquer. It was found that linear programming enabled the formulator to obtain the optimal solution in a small number of formulating steps.

2.4.6 Detergent Formulation

Chan and Kavanagh (1988) used linear programming to obtain a good, low cost light duty liquid detergent formulation which matched or exceeded the properties of a commercially available product in a small number of formulation steps. The strategy was a sequential procedure, making use of a formulator's prior knowledge of the product, product attributes obtained from each formulation, regression analysis and linear programming. The linear model was improved at each step. In comparison with previously published methods of detergent formulation, a considerably smaller number of steps was required to arrive at a minimum cost formulation which met the product property specifications.

2.5 LP88 COMPUTER PROGRAM

There are many commercial computer programs available to solve the linear programming problem. Chan and Kavanagh (1988) used the package, LPBEST (Deakin University Computer Center, Victoria, Australia) to solve the linear programming model for liquid detergents. Craig et al. (1989)

used LINDO commercially available software in the processed cheese formulation.

In this study LP88 was used to solve the linear programming problems for the hand cream formulation. LP88 is a computer program used for linear programming problems. It is a product of Eastern Software Products in the United States. This is a relatively flexible and easy to use package. It does not require an advanced knowledge of linear programming. It will handle problems of quite reasonable size:

up to 1000 constraints
up to 5000 variables.

LP88 is a general-purpose system for solving linear programs using an IBM PC or a compatible personal computer. The program is designed to be useable over the widest possible range of equipment configurations and application environments (LP88, 1987).

Linear programs can be input as they are formulated without being converted to a standard form. Both maximization and minimization problems are accepted. Constraints may be any combination of equations or linear inequalities in the variables. The objective and any of the constraints of a linear program can be input as equations. LP88 will evaluate nonlinear expressions and functions at the origin and insert a linear approximation for the formula. LP88 has the ability to convert a linear program into its dual and vice versa. The dual problem is constructed on command according to the standard mathematical rules and replaces the original linear program as the current problem.

2.6 DISCUSSION

According to Nicklin (1979) linear programming has several advantages over the traditional qualitative methods used in product formulation studies. They are:

* It eliminates the guess work and subjectivity associated with the conventional approach.
* It is less laborious and time consuming especially when many constraints are included.
* It minimises cost, not only of the product but the formulation work itself.

Linear programming was chosen to determine the hand cream formulation for the following reasons. It provided a means of:

* determining the least cost formulation relatively quickly and efficiently.
* sensory constraints can be put in the model to generate the optimal solution.

CHAPTER 3

QUANTITATIVE SENSORY PROFILING

3.1 INTRODUCTION TO SENSORY PROFILING

Sensory profiling represents the most sophisticated of the available sensory methodologies compared with discrimination and acceptance testing methods. Sensory profiling results include a complete sensory description of the test products and provide a basis for determining the sensory characteristics that are important to acceptance, as well as an aid in identifying underlying ingredient and process variables; that one is able to relate specific ingredients or process variables to specific changes in the sensory characteristics of a product.

Sensory profiling consists of three major procedures: Flavour Profile developed by the A.D. Little Co., Cambridge, Massachusetts in the late 1940s. (Cairncross and Sjöström, 1950), Texture Profile developed at the General Foods Research Centre (Brandt et al., 1963; Szczesniak, 1963), and quantitative descriptive analysis (QDA) developed by Stone et al. (1974).

The Flavour Profile method involves the analysis of a product's perceived aroma and flavour characteristics, their intensities, order of appearance, and aftertaste. This method utilizes a panel of four to six screened and selected subjects who first examine and then discuss the product in an open session. Once agreement is reached on the description of the product, the panel leader summarizes the results in report form.

Based on the principles of the Flavour Profile method, the Texture Profile method was developed by Brandt and Szczesniak to define the textural parameters of foods. Later the method was expanded by Civille and Szczesniak (1973) and Civille and Liska (1975) to include specific attribute descriptors including semisolid food, beverages, skin care products and fabric and paper goods. Panelists are selected for training then exposed to a wide range of products from the category under investigation, to provide a wide frame of reference. Panelists define all terms and procedures for evaluation, thus reducing some of the variability encountered in most descriptive testing. The reference scale used in the training of panelists can later serve as references for approximate scale values, thus further reducing panel variability.

Samples are evaluated independently by each panelist using a scaling technique, i.e., category, line or magnitude scales. For the final report, data may be displayed in tabular or graphic form.

In response to dissatisfaction among sensory analysts with the lack of statistical treatment of data obtained from the Flavour Profile or related methods, a method of sensory evaluation called quantitative descriptive analysis (QDA) was developed at the Stanford Research Institute (Stone et al., 1974). QDA method relies heavily on statistical analysis to determine the appropriate terms, procedures, and panelists to be used for analysis of a specific product.

3.2 SCALING METHOD USED IN QUANTITATIVE SENSORY PROFILING

In sensory profiling, several scaling methods have been used by many researchers. Selection of the most appropriate technique for measuring the response of the subject to a stimulus (the perceived sensory attribute of a product) was considered basic to the development of the sensory profile technique. The choice of the scale was influenced by the work of Baten

(1946) and a subsequence study by Hall (1958). Baten showed that a scale word-anchored only at the ends yields greater product differences than the typical category scale. Hall used a technique that was a variation of the Flavour Profile procedure. After round table discussion panelists were provided with a rating form listing each attribute along with a linear scale with words at each end. The subject's score was then converted to numerical rating for subsequent analysis. He reported that this method provided a continuous rather than stepwise scale, and that a scale without numbers eliminated possible bias for particular numbers.

The removal of numbers from the scale eliminated two sources of bias. The first source of bias was avoidance of (or preference for) particular numbers that have negative (or positive) connotations. The second source of bias was some subjects tend to change use of numbers over time. The researcher might not know if this change reflected a product difference or true bias.

The data which are obtained from a linear scale are continuous and the panelists are not forced to make their perceptions match particular numbers such as 1, 2,..., 8, 9. Continuous data such as scale values have at least two advantages. First, the panelist do not have to fit their perceptions into specifically designated categories; second, continuous data are more likely to meet an assumption implicit for ANOVA, namely, the errors are normally distributed (Powers, 1988).

Weiss (1972) has described a scaling method called 'graphic rating' in which the subjects are provided with reference stimuli at each test session.

Stone et al. (1974) developed a scaling method to use in descriptive analysis. The scale is an interval scale with the following features: a line of specific length-6 inches (or 15cm) - with anchor points 1/2 inch (or 1.5cm) from each end; usually but not necessary a third anchor at the midpoint; and usually one word or expression at each anchor. The anchor is put at 1.5 cm from each end to provide a little leeway for a panelist who has used all the scale, then encounters a sample which he or she thinks should be rated stronger (or weaker) in intensity than any sample previously encountered. The subject has the task of placing a vertical mark across the line at that point which best reflects the magnitude of his or her perceived intensity of that attribute.

The use of more than two anchors tends to reduce the line scale to a category scale, which may or may not be desired. Shifting the anchors to the ends of the line would also have a dramatic effect on responses; response pattern would take on the character of a true category scale and greater departure from linearity (Stone and Sidel, 1985). Normally the left end of the scale represents a small amount or a very weak level of the stimulus and the right end represents a large amount or a very strong level of the stimulus. In some cases the scale is bipolar, i.e., opposite types of stimuli are used to anchor the end points.

After the panelists have completed their judgments, the experimenter superimposes a grid dividing the line into 60 units, to assign a number between 0 and 60 to each rating. These values are then tabulated. Panelists do not discuss data, terminology, or samples after each test session and must depend on the discretion of the panel leader for any information on their performance relative to other members of the panel and to any known differences between samples.

3.3 TRAINING OF PANELISTS FOR QUANTITATIVE SENSORY PROFILE

3.3.1 Selection of the panelists

Panelists are selected from a large pool of candidates according to their ability to discriminate differences in sensory properties among samples of the specific product type for which they are to be trained.

Panelists can be recruited either from the in-house employees of the company or by obtaining consumers through telephone recruitment or the use of an outside agency.

Zook and Wessman (1977) suggested that candidates for quantitative sensory profile panels be screened for their discriminating ability by applying the triangle test. In the triangle test, the panelist is presented with three coded samples, two of which are the same and one of which is different. The panelist is asked to select the odd sample. They considered that a would-be trainee for descriptive analysis should be at least 70% successful in selecting the odd sample; otherwise the individual should be rejected. However, this also depends on the test samples. If the test samples are very difficult to identify, 66-67% correct response can be accepted.

Gacula et al. (1974) and Word and Gress (1981) similarly recommended the use of the triangle test except they combined it with sequential analysis to lessen the amount of testing required. Candidates who demonstrate ability to discriminate are permitted to go to the next stage, which is training in sensory profiling.

In addition to performance, availability is very important in panelist selection, because the panelists must be able to come to all of the sessions.

3.3.2 Training

Unlike a Flavour Profile or Texture Profile panel, a quantitative sensory profile panel are normally charged with the evaluation of only one type of product. Different panelists are trained for different products (Powers, 1988).

The training of quantitative sensory profiling panels requires the use of product and ingredient references, as with other sensory profile methods, to stimulate the generation of terminology. The panel leader acts as a facilitator, rather than as an instructor, and refrains from influencing the group. The panel leader keeps the group functioning, provides standards and training samples as needed, prepares trial scoresheets, thinks of the ways to clarify confusion, tests and monitors the panelists' performance.

In this method, the panelists are trained using the test products, not model systems. To achieve a good statistical analysis of the performance of the panelists, Stone et al. (1974) recommended that as many as 12-16 replicate judgements per panelist may be needed. However, Powers (1988) stated that four to six replications should be enough.

3.3.3 Development of Descriptive Terms

One of the problems of sensory profiling is the development of a list of descriptors characteristic of the particular product being evaluated. The vocabulary may have to be formulated during training or there may have been prior development of a vocabulary which the panelists now have to be trained to use.

Stone et al. (1974) stated that the panelists and the leader should participate in the development of the language but that the leader would not actively participate in product evaluation.

Panelists have to be familiar with the terms which are used to evaluate the product, then they can give accurate results. Many researchers have found that panelists can give precise results when they are trained many times.

The successful use of a linear scale is dependent on the instruction and the frame of reference provided to make the scale 'functional'. During language development, subjects are familiarized with the scale and its use, with particular attention given to the anchor terms relative to specific samples that will be evaluated. Functional measurement requires that the subject experiences what constitutes the extremes in intensities for many of the terms used to describe product attributes. This procedure helps to minimize end-order effects (avoidance of the extremes) and encourages full use of the scale to express product differences.

In panel training, practice has to be acquired in scaling of the sensory materials for the intensities of the different attributes agreed upon. For training, usually not less than four replicate sessions are held; more may be needed. During training, the samples are brought closer and closer together in terms of their differences by blending samples or by selecting samples known not to differ greatly in their sensory qualities. ASTM Committee E-18 (1981) describes the procedures generally followed to train panelists for descriptive analysis.

3.3.4 The Quantitative Sensory Profile Test

Quantitative sensory profiling panelists evaluate products one at a time in separate booths to reduce distraction and panelist interaction. The subject is asked to place a vertical mark across the line at that point which best reflects the magnitude of his or her perceived intensity of that attribute. By measuring the distance along the line to the mark, a numerical value is obtained for computation.

The results of a quantitative sensory profiling test are analyzed statistically using the analysis of variance, and the report generally contains a graphic representation of the data in the form of a 'spider web'. This is a graph with lines representing the sensory attributes radiating from a centre point, 0 to 60 (or other value) at the edge. The numerical mean ratings for each attribute are located at the proper points on these spokes and are connected by lines to give a graphic picture of the descriptive results. This presentation makes it possible to see at a glance the differences and similarities of several products displayed on the same spider web.

This is usually backed up by supporting tables of the actual product means for each attribute arranged in descending order with associated tests of significance. The data can be displayed in many other ways, but this particular method has proven to be an easy to understand format for presentation of the sensory data.

The analysis of variance (ANOVA) model is the most appropriate statistical procedure for analyzing responses. The analysis of variance enables the researcher to determine whether the mean scores for several products differ from one another in sufficient magnitude to justify considering them different at some stated level of risk. The magnitude of the difference between products is reflected in an F ratio and its corresponding probability value. The smaller probability values reflect greater difference between products.

3.4 APPLICATIONS OF QUANTITATIVE SENSORY PROFILING

There are many applications of quantitative sensory profiling as follows:

i) Monitor competition. It is important to know in what ways competitive products differ; such information can be used to anticipate changes and to identify product weakness.

ii) Storage testing. In a storage test in which product changes occur over time, descriptive analysis at the start of the test provides a basis on which changes can be compared. A major problem in all storage tests is the availability of a control product throughout the study. The quantitative sensory profiling method eliminates the need for the control product.

iii) Quality control. During processing, consideration must be given to the step where the potential for variability is high and will result in a noticeable defect in the finished product. Sensory profiling may be helpful, at least during the investigative stages, to identify at which step in the process the most change has occurred. It could be used to identify the sensory limits for a product. The purpose is to identify any trends away from the sensory limits and to provide a day-to-day independent check on evaluation. The data may be plotted against the reference standard to determine whether the finished product is within acceptable limits.

iv) Instrument - sensory relationships. This method is helpful in identifying specific product differences that can be related to differences in instrument measures.

v) Research and development. Quantitative sensory profiling provides a way to describe new products, changes in formulation, and methods of manufacture. It becomes a useful tool when ingredients become unavailable or a product was to be cost-reduced.

In product development tasks, one can use quantitative sensory profiling to evaluate products and apply the results to ingredient selection, and to the matching of target attributes. When the decision is made by the researcher that sensory profiling is appropriate, it is then necessary to plan the test, select the product, and decide on the size of the data base that will be developed.

In product optimization, the objective measure obtained from the experiment should be suitable for calculation in order to get the optimal solution for the formulation. Hence, quantitative sensory profiling is the most suitable procedure to be considered.

3.5 IDEAL PRODUCT PROFILING

The ideal product profile is obtained by asking consumers to indicate their ideal product on preselected attributes. This has been used in development of many products (Moskowitz, 1984; Cooper et al., 1988). Since it was found that the ideal absolute score itself was not useful in quantitatively measuring how the different product prototypes were nearing the optimal product, the ideal ratio score was introduced to the product development system (Cooper et al., 1988). Ideal ratio scores, the ratio of the product score to the ideal score, were used to decide the size and direction of product changes required to reach the consumers' ideal product. Ideal ratio score has been used successfully at Massey University for many years (Sinthavalai, 1986; Lai, 1987; and Wiriyacharee, 1990). Beausire and Earle (1986) stated that mean ratio scores could be used in factorial experimental designs to give empirical equations which could be used to predict the levels of ingredients or processing conditions necessary to give optimum sensory characteristics.

3.6 USE OF QUANTITATIVE SENSORY PROFILING IN SKIN CARE PRODUCTS

The sensory properties of skin care products are important to product success in the marketplace. The information can be used in product formulation, for measuring of competitive products, or for cost reduction by substitution with low cost ingredients.

Goldemberg and de la Rosa (1971) established a sensory evaluation system leading to a quantitative value for 'Skin Feel Index' and correlated it with the various emolient ingredients in the preparations studied. The proposed 'Skin Feel Index' was defined as the ratio of 'Initial Slip' (i.e., degree of slip on initial evaluation, rated on a 1-5 scale) to 'Total End Feel' (i.e., overall feel after complete dry-out, rated on a 4-20 scale). The latter was a summation of ratings (1-5 scale) for smoothness, friction, oiliness and moistness. Other studies (e.g., Gibson, 1973) on hand care preparations showed that panel evaluations are meaningful in predicting the consumer response. Barry and Grace (1972) used various scaling methods and correlated panel ratings of spreadability with instrumental measurements of rheological properties. They found that ordinal scaling, ratio scaling, and preference rating all gave meaningful results.

Mitsui et al. (1971) studied the rate of shear encountered in topical application of cosmetic creams and lipstick by dividing the application velocities by the applied thicknesses of the layer.

Schwartz (1975) showed how the principles of sensory texture profiling were applied to the evaluation of skin care products and how the basic methodology was modified to accommodate problems unique to this type of products. Schwartz suggested that the perception of texture comprises the following phases, which occur in sequence:

i) Pick-Up - the removal of the product from the container;
ii) Rub-Out - the application of the product to the skin, and
iii) After-Feel - the evaluation of the effect of the product on the skin.

In her study, a wide variety of ingredients were screened and selected for use in finished products. Prototypes were evaluated in comparison with commercial products and results used successfully in predicting consumer response.

Moskowitz (1984) has described using descriptive analysis to profile products in terms of a desired 'sensory signature' and then to select those particular prototypes that possess the desired signatures. Rapid Clean Corporation wanted to make a new hand cleaner to satisfy consumers. The research and development group prepared 25 alternative test formulations, comprising different levels of consistency, different colours, and different fragrances, respectively. Informal benchtop screening quickly reduced the number of feasible alternatives to seven plus the current competitor, these varied primarily in fragrance type and consistency. The product development and marketing research groups used descriptive analysis and scaling to select the particular prototypes that would best answer the consumers' need.

Consumers were asked to profile each of the eight hand cleaners on the different sensory characteristics. Then the consumers rated each test cleaner as well as the major competitor on a variety of sensory characteristics (depth of colour, fragrance strength, and greasiness), a performance characteristic (ease of spreading), and overall acceptance to generate a more complete product profile for each product. The researcher asked consumers to describe the sensory characteristics of each fragrance using a detailed list of terms. The consumers were then asked to profile their 'ideal' product using the same set of attributes and scales that they had used to describe the actual products.

From the sensory profiles of prototypes and competitors, and the level of the fragrance and textural characteristics desired by the consumer, it became possible to determine which attributes of each prototype come closest to the ideal, and which attributes need modification and to what degree. Such a profiling method helps the manufacturer to determine what to do next in a product development project.

3.7 CONCLUSION

Since quantitative sensory profiling results are analytical and quantitative, it was chosen for the development of new hand cream products in this study. Regressions were applied to the results to establish the empirical equations showing relationships between the various sensory attributes and input variables. Then these equations were used in a linear programming model to generate the optimal solution.

In the next chapter, hand cream which is the product to be evaluated by quantitative sensory profiling will be reviewed.

CHAPTER 4

THE FORMULATION AND TESTING OF HAND CREAM FORMULATIONS

The aim of this chapter was to review the raw materials, properties of hand cream, formulation and the methods used for processing and testing hand cream. The basic formulation and processing used in this project are also described. The objectives were:

* To obtain the basic formula to be used in further experiments.

* To obtain hand cream samples for panel training.

4.1 INTRODUCTION

Skin care products are the products which occupy the biggest market in the cosmetic and toiletries area. Facial moisturizing products are the predominant products in the skin care product category followed by hand and body preparations and cleansing products. Although the skin care products account for a large proportion of the total market, the growth of the market is very slow. Therefore, the manufacturers have to consider various ways to develop new products. The product of interest in this study was hand cream, which will be discussed in detail, examining raw materials, processing methods, formulation and testing methods in this chapter.

Harry (1973) mentioned that a hand cream is expected to fulfil the following functions:

* To provide a source of moisture readily available to the skin.

* To provide an oil film with properties not very dissimilar to those of sebum.

* To leave the hand feeling subjectively smooth and supple but not excessively greasy.

* To apply easily in a controllable manner.

The consumer requirements will depend on the extent to which the hands are damaged or water deficient, and the product can range from a light lotion providing little more than moisture emollience and a pleasant perfume, to the near-therapeutic product for treating damaged skin.

In general, hand creams need to be very light creams which rub in quickly leaving the skin soft but not sticky or greasy.

4.2 RAW MATERIALS

Since hand cream is designed to be in contact with tissues of the human body, a most important consideration for choosing ingredients to be used in hand cream is their safety. Hand creams are left on the skin after application for extended periods of time. Consequently, it is most important that the chemicals and ingredients used for their preparations should be free of physiologically harmful effects (Breuer, 1985).

The basic formulation for hand cream is composed of moisturizing agents, emulsifying agents, preservatives, and antioxidants.

4.2.1 Moisturizing Agents

If water is lost more rapidly from the stratum corneum than it is received from the lower layers of the epidermis then the skin will become dehydrated and lose its flexibility. Moisturizing agents are used in hand cream because of their two important mechanisms: the prevention of water loss from the skin, which allows build up of water content from within, or supplementing the skin's water content by attraction of water from the atmosphere by means of a humectant material which serves as a transfer medium. The following moisturizing agents are used frequently in hand cream products.

* Mineral oil. Mineral oil is the one single component used most frequently as moisturizer. It functions by covering the skin with a hydrophobic occlusive film which prevents water loss to the environment, thereby promoting hydration of the corneum by allowing water diffusing from the underlying tissues to accumulate in the corneum. However, because the solvent action of mineral oil tends to remove skin surface lipids when cosmetic cream is applied for a short period of time, partial replacement with a vegetable oil is needed (Grayson and Eckroth, 1979).

* Propylene glycol and glycerine. In facial preparations, propylene glycol is used almost three times more frequently than glycerine. In the hand and body creams however glycerine is used almost twice as frequently as propylene glycol (Fox, 1984). Powers and Fox (1959) showed that 15 percent glycerine lowered skin roughness and skin friction.

* Fatty alcohols. The fatty alcohols, such as cetyl and stearyl alcohols, are hydrophobic; hence they produce occlusive films that aid in inducing hydration of dry skin. In addition, they have sufficiently high melting points to deposit nongreasy films on the skin. They not only serve as moisturizing agents but also confer emulsion stability, help control viscosity and consistency and also leave a smooth finish on rub-out.

* Lanolin and lanolin derivatives, such as liquid lanolins, lanolin

wax, lanolin alcohols and modified lanolin. Lanolin is a natural wax and the hydrophobic and adhesive character of lanolin makes it an excellent occlusive agent and hence good emollient. The proportion of lanolin generally used in hand creams and lotions is not more than 5% because of its tackiness which is imparted to the end product if the concentration is too high.

* Fatty acids. The fatty acids constitute the class of basic ingredients most widely used in the formulation of hand creams and lotions. Although fatty acids ranging from C_{12} to C_{18} have been experimentally tried in the development of these products, stearic acid alone is the fatty acid of choice (Strianse, 1972). As an emollient, stearic acid falls into the category of occlusive agents, but because of its dry and nongreasy nature which differs from most of the other occlusive emollients, its deposition on the skin in the form of a thin film is not objectionable. Most hand creams and lotions contain stearic acid. In some formulations, it appears as part of the emulsifier (such as potassium stearate or triethanolamine stearate) but in most cases it also present as the free acid.

* Esters such as isopropyl myristate and isopropyl palmitate. They are widely used as moisturizing agents in most skin care products but they are not predominant raw materials. Isopropyl myristate is a quickly absorbed substance so it is used to formulate a product which dries very quickly with no oily or greasy finish.

* Vegetable oils, such as sweet almond oil, olive oil, rice bran oil. Vegetable oils do not soak into the skin rapidly, therefore they are used to produce a 'dewy' moist finish moisturizing lotion and cream. Now the potential of cosmetics is leaning towards naturalness, concern for environment, and a desire not to have to question either safety or efficacy. These raw materials will tend to play an important role in the cosmetic industry.

4.2.2 Emulsifying Agents

An emulsion is required in hand creams because of five desirable qualities (Fox, 1986):

i) Compatibility of ingredients. Moisture, antioxidant, fragrances, preservatives can be combined into what appears to the consumers to be a homogeneous product.

ii) Consumer acceptance. Hand creams consist of oils which provide the needed skin moisturization emolliency and softness but they are not greasy to touch or rub out because of the emulsion system.

iii) Physical characteristics. Use of an emulsion vehicle allows the formulator to develop products with widely different physical characteristics, e.g. viscosity, time to work in.

iv) Fragrance. A much wider variety of aromas can be attained in o/w emulsion, than in straight oils.

v) Economy. The cost of the creams can be controlled by the quantity of water contained in the formulation.

Emulsifying agents are divided into 4 major groups: anionic, cationic, amphoteric and non-ionic, according to their behaviour as described in detail by Fox (1974).

In general the soap/monoglyceride emulsion system is the mainstay in most skin care products (Fox, 1984). The monoglycerides are supplied in self-emulsifying mixtures and the manufacturers have added an emulsifying agent which may be a soluble soap, anionic surfactants, nonionics and cationics as the emulsifying aids. Glyceryl monostearate is the most popular monoglyceride in use. It provides the cream with smoothness and fine texture and improves stability (Harry, 1962).

The soaps used in hand creams and lotions are mainly potassium and triethanolamine salts of stearic and palmitic acids. In most instances when a soap is used as the emulsifier in oil-in-water emulsions it is formed 'in situ'; that is, it is formed during the emulsification process. Triethanolamine soaps are excellent emulsifying agents for cosmetic preparations. They provide flexibility in formulation, have a low sensitivity to temperature change. The resulting emulsions are essentially neutral and have no injurious effect on the skin. They give creams of desirable texture and consistency that are unaffected by moderate changes in temperature. Mineral oils, petrolatum, lanolin, vegetable oils, beeswax, and many other ingredients can be dispersed evenly in such emulsions. Fox (1986) stated that a combination of triethanolamine stearate and stearic acid will result in a more stable emulsion than by using the soap alone.

4.2.3 Preservatives and Antioxidants

Since hand creams contain water and materials that are subject to decomposition by microorganisms, they must be protected against such attacks. Preservatives are required to minimize the growth of microorganisms both during manufacture and once the product reaches the consumer (Rigler and Schimmel, 1957).

In selecting the preservative the following areas have to be considered (Sabourin, 1986):

* Effectiveness of the preservative against microorganisms.
* Compatibility with other ingredients in the formulation.
* Safety of the preservative.
* Cost effectiveness.

The parabens (methyl paraben and propyl paraben), imidazolidinyl urea and quaternium 15 are the preservatives used most frequently. EDTA and its salts are used quite frequently in formulations containing parabens as they undoubtedly enhance the antimicrobial efficacy of these preservatives (Fox, 1984).

Addition of antioxidants in hand cream is required to prevent oxidation of oil incorporated in the product. Antioxidants chosen appear to be BHA, BHT, and tocopherols (vitamin E).

4.3 PROPERTIES OF HAND CREAM

4.3.1 Appearance and Feel

Hand creams can vary in appearance with respect to viscosity, pour characteristics, gloss, smoothness, pearlescence, texture, and opacity; they vary in application and feel in terms of oiliness, tackiness, wetness, slip, grittiness, spreading qualities, and drying time (Fox, 1974). These depend on the formulation chosen and processing condition.

4.3.2 Rheology of Hand Creams

Rheology deals with the deformation and flow of materials, and in hand creams the viscosity or consistency is of considerable interest.

Viscosity or consistency offers resistance to flow and is defined as the fluid's resistance to change in form due to internal friction. It is a very important parameter in hand creams since a product is designed for a given feel and to be dispensed from a specific bottle or tube opening. Accordingly the viscosity should not change appreciably with age.

The viscosity of the hand cream can be controlled by increasing the viscosity of the continuous phase. In the case of oil-in-water emulsions this can be accomplished by adding synthetic and natural gums, clays, and certain emulsifiers, such as potassium and sodium soaps.

4.3.3 Stability

One of the primary objectives in cosmetic product development should be the development of a product that has the desired appearance, feel, and functionality and will have a saleable shelf life for at least several years. The product should be stable during storage, in particular there should be no breakdown of the emulsion, growth of microorganisms, development of off-odours or discolouration.

The product should also be stable to freeze-thaw conditions, which may occur in shipping, and to storage temperatures of 37 and 45 °c, which may readily occur in many parts of the world during the summer and especially on storage in warehouses during the summer months.

The stability and consistency of hand creams depends on the choice of the components and their relative proportions in the formula, the temperature of the two phases at the time of emulsification, the speed of stirring, the duration of stirring, and the rate of cooling.

4.4 PROCESSING

The choice and development of suitable manufacturing processes has important effects on the attributes of hand creams. The consumer acceptability and perception of quality of hand creams depends on their rheological properties. These properties are strongly affected by the manufacturing processes used.

Fox (1974) recommended that in laboratory product development work the equipment used should simulate the manufacturing equipment that will be required for commercial production, and one should avoid using equipment in the laboratory that could not be available for manufacturing.

Initial formulation work is usually carried out in convenient size glass or stainless-steel beakers, using a suitable motor stirrer. If soap is used as the emulsifier, it is usually prepared in situ; that is, the alkali is mixed with the water phase, and the fatty acid is included in the oil phase. When other emulsifying agents are used, the oil-soluble agent is dissolved in the oil phase, and the water-soluble agent is dissolved in the water phase (Fox, 1974). The method of addition of the oil and water phases, the rates of addition, and the temperature of each phase have some effect on the droplet-size distribution, viscosity, and stability of the final emulsion.

After the emulsion has formed at an elevated temperature, the rate of cooling is extremely important in determining the final texture and consistency of the emulsion. This is due to the type of crystallization of some of the high-molecular-weight components, such as beeswax, stearic acid, cetyl alcohol, and glyceryl monostearate. Each product must be studied to determine the best cooling rate.

4.5 EQUIPMENT

There are many types of stirrers to choose from in preparing creams and lotions, and the unit selected will depend on the particular emulsion being considered. For low-viscosity preparations, a simple propeller mixer used in conjunction with a rheostat or Variac to control mixing speed is usually sufficient. Where more vigorous agitation is desired or where moderate viscosity fluids are to be mixed, turbine-type mixers are employed. When very high shear rates are desired (e.g. for creams and lotions with small droplet sizes), ultrasonic mixers, colloid mills, or homogenizers are used.

4.6 METHOD OF TESTING

In order to attain a product which contains acceptable properties, product testing has to be done for both product prototype and finished product. Normally, both physical testing and sensory testing are used in hand cream testing.

4.6.1 Physical testing

The physical attributes of the hand cream samples tested in these experiments were viscosity and consistency.

* Viscosity

Ferranti-Shirley cone-plate viscometer was used in this study. Sherman (1970) noted that Ferranti-Shirley was used by many researchers to measure viscosity of pharmaceutical and cosmetic products, such as: procaine Penicillin G suspension, ointments, creams, and pastes. The cone-plate viscometer is suitable for measuring Newtonian and non-Newtonian samples (Sherman, 1970).

The cone-plate viscometer measured viscosity by a rotating small angled cone and a stationary lower flat plate. Three cones were available - large, medium and small. Apex of the cone just touched the plate, and the sample was sheared in the gap between. Viscous drag on the cone exerted a torque on an electromechanical torque dynamometer. Less than 0.5 ml sample was required. Samples were measured at room temperature.

The viscosity was calculated using the equation shown below. The meter divisions were obtained from the recorder connected to the viscometer, K_n is supplied for all the cones furnished with the viscometer, rpm is the selected cone rotational speed.

$$\text{Viscosity} = K_n \times \frac{\text{meter divisions}}{\text{rpm}} \text{ (poise)}$$

* Consistency

The Bostwick consistometer measured the consistency of viscous materials by measurement of the distance over which the material flowed on a level surface under its own weight during a given time interval. The test material was held at the end of a metal trough by a gate which was opened instantaneously by release of a spring. When the gate was released the product flowed out because of the hydrostatic head produced by the weight and height of the product before it was released by the gate. Samples were measured at room temperature.

Usually the consistency of a sample is expressed as the distance over which the sample flows on a level surface in 30 seconds. This empirical value can be converted to apparent viscosity via conversion charts supplied by the manufacturers of the instrument, or calibrated by reference to standard sugar solutions (Kramer, 1970). But in these experiments it was used directly.

4.6.2 Sensory testing

In sensory testing, much research has been done to obtain the best way to evaluate skin care products and to relate sensory evaluation with input variables (raw materials) (Goldemberg and de la Rosa, 1971; Schwartz, 1975; and Moskowitz, 1984). Most of the methods have been adapted from the ones used for evaluating food and beverage products. Both trained panels and consumer panels are used during product formulation.

In this study, a consumer panel was used to generate the product profiles of competitive products and the consumer ideal product profile at the beginning of the research and was used to test the finished product after optimization. A trained panel was used for sensory evaluation during prototype development.

4.7 HAND CREAM FORMULATION AND SELECTING OF FORMULATION

Those properties of hand creams, including stability and emulsion type, are in a large measure dependent on the physical and chemical properties of the oil and water phases, the phase-volume ratio of the oil and water phases, the concentration of the surfactants used as emulsifying agents, the type of mechanical emulsifier used for emulsification, and the method and rate of cooling.

The appearance of an emulsion is dependent on the particle size of the dispersed phase. Hand creams may range in appearance from clear solubilized oils with extremely fine dispersed-particle size to milky white creams with relatively large-sized dispersed-phase droplets or particles. Cosmetic creams may have a matte finish or a pearly appearance, depending on the ingredients used. Pearly appearance is most likely to develop in products containing stearic acid, cetyl alcohol, stearyl alcohol, or some of their derivatives, and the rate at which the pearly appearance occurs is dependent on the rates of cooling and crystal growth.

The application properties of a hand cream are related to the ingredients and emulsion type. Hand creams with a high oil content will form an oily film on the skin; hand creams based on solid fatty alcohols, fatty acids, esters, and waxes usually form a dry film on the skin. Polyols included in a cosmetic cream at high concentrations often make a cream or lotion feel moist on the skin, and oil-in-water emulsion type creams in general are less oily in feel than water-in-oil ones.

Formulations of hand creams are given in many books on cosmetics, e.g. Harry (1974), Fox (1974). Formulae differ depending on the purpose of the hand cream, the physical and sensory attributes wanted by the manufacturers.

The following formulae were selected for the preliminary experiment because they contained small amounts of mineral oil, and were not complicated formulae, the last two formulae also included rice bran oil in the formulae.

FORMULA 1: derived from Miranol (1989)

		%
A.	Glyceryl monostearate	5.00
	Mineral oil	10.00
	Stearic acid	2.00
	Beeswax	1.00
B.	Deionized water	81.20
	Triethanolamine	0.80

FORMULA 2: derived from Harry (1973)

		%
A.	Stearic acid	6.00
	Mineral oil	10.00
	Silicone	1.00
	Arlacel 83	1.00

B.	Triethanolamine	2.00
	Water	80.00

FORMULA 3: derived from Harry (1973)

		%
A.	Stearic acid	3.00
	Lanolin	2.00
	Beeswax	2.00
	Mineral oil	23.00
	Arlacel 83	1.00
	Sorbitol solution	10.00
B.	Water	59.00

FORMULA 4: derived from Loo (1976)

		%
A.	Rice bran oil	5.00
	Glyceryl monostearate	2.00
	Sorbitol solution	18.00
	White petrolatum	19.00
B.	Water	56.00

FORMULA 5: derived from Loo (1976)

		%
A.	Rice bran oil	5.00
	Mineral oil	8.00
	Glyceryl monostearate	10.00
	Glycerine	5.00
	Stearic acid	2.50
B.	Triethanolamine	1.50
	Water	68.00

Samples of all of these formulae were made in order to choose the most suitable one for further experiments.

Table 4.1 Physical Properties and Appearance of Hand Cream Made from Selected Formulae

Formula	Viscosity (poise)	Appearance
1	7.2	White colour, soft cream
2	0.5	Runny with small bubbles in the product
3	30.2	Solid cream, grainy
4	28.3	Water phase separated from oil phase after the product cooled down
5	10.1	Homogeneous soft cream

From the appearance and physical properties of these samples, Formula 5 had the most potential to be developed because rice bran oil was included in the formula and it gave a nice hand cream with a medium range viscosity so it was possible to increase or decrease viscosity if necessary. Therefore this formula was chosen to be the basic formula in the hand cream development. A quarter replicate 2^5 factorial design around this formula, was used to identify samples for the panelist selection and panelist testing which is described in Chapter 6.

The quarter replication of the 2^5 factorial design of the selected hand cream formulation and the viscosities of the hand cream from the eight treatments measured by Ferranti-Shirley viscometer are shown in Table 4.2.

Table 4.2 Fractional Factorial Design for 5 Variables in Hand Cream Formulation

Run	Treatment code	% of Total Mix					Vis. (poise)
		A	B	C	D	E	
1	1	5 (-)	1 (-)	3 (-)	3 (-)	1 (-)	2.15
2	bc	5 (-)	8 (+)	10 (-)	3 (-)	1 (-)	6.08
3	ad	10 (+)	1 (-)	3 (-)	5 (+)	1 (-)	2.01
4	abcd	10 (+)	8 (+)	10 (+)	5 (+)	1 (-)	8.32
5	be	5 (-)	8 (+)	3 (-)	3 (-)	3 (+)	3.19
6	ce	5 (-)	1 (-)	10 (+)	3 (-)	3 (+)	6.22
7	abde	10 (+)	8 (+)	3 (-)	5 (+)	3 (+)	4.20
8	acde	10 (+)	1 (-)	10 (+)	5 (+)	3 (+)	7.32

A - Mineral oil

B - Rice bran oil

C - Glyceryl monostearate (self-emulsifying agent)

D - Glycerine

F - Stearic acid

The remaining ingredients and the process variables were set at the levels shown below:

* Triethanolamine (85%) 1.5%
* Water - to balance formulation to 100%
* Mixing temperature 70 - 75 °c
* Mixing time 2 minutes

In panelist selecting, section 6.1 (Chapter 6), samples from Formula 1 (lab code F-1), Formula 2 (lab code F-2), Formula 3 (lab code F-3) and Formula 5 (run 1, 6, 7, and 8; lab code R-1, R-6, R-7, and R-8 respectively) were used.

In panelist testing, section 6.2 (Chapter 6), samples from run 1, 3, 4 and 6 were used and were coded as follows:

	coded number
R-1	307
R-3	452
R-4	569
R-6	726

These samples were chosen because they ranged between low, medium and high viscosity and they also varied in terms of some sensory attributes according to the experimenter's judgment.

4.8 PLANNING FOR HAND CREAM EXPERIMENTS

4.8.1 Selection of Raw Materials

* Mineral oil - as moisturizing agent
* Rice bran oil - as moisturizing agent
* Glycerine - as moisturizing agent
* Stearic acid - as moisturizing agent and to form a soap with triethanolamine in emulsion system
* Glyceryl monostearate (self-emulsifying agent) - as emulsifying agent
* Triethanolamine - as emulsifying agent
* Water - as continuous phase in emulsion system

Preservatives were not included in the formulation since they were assumed not to have any effects on the attributes of the samples in this study. Rice bran oil has tocopherols which are natural antioxidants so there was no need to add antioxidant in the formulation.

4.8.2 Method

In preparing hand cream, the water phase (water and triethanolamine) was placed in the glass beaker and heated on an electric hot plate to 70-75°c. The oil phase (the remaining raw materials) was heated in a glass beaker to 70-75°c.

When the aqueous and oil phases were homogeneous and at the correct temperature, the oil phase was added slowly to the water phase with rapid agitation, but avoiding the formation of a vortex, to minimize the incorporation of air.

After the emulsion had formed it was allowed to cool down under ambient conditions. The stirring, at low speed, was continued until the temperature dropped to 45-50°c.

4.8.3 Emulsifying Equipment

In this study, a Silverson homogenizer mixer was used. It is a mixer with built-in homogenizing action. This mixer uses a high-speed turbine-stator mechanism to create stable emulsions and suspensions. Mixing and homogenization are carried on by immersing the homogenizing head (turbine-stator) in the mixing container. The turbine rotates at high speed and creates a pressure differential between the bottom of the turbine and the surface of the material being processed.

In the next chapter the consumer testing, which was the first step of product optimization for the hand cream product is discussed.

CHAPTER 5

CONSUMER TESTING

5.1 AIM

The aim of this consumer testing was to study how consumers reacted to the hand creams available in the New Zealand marketplace. And the objectives were:

* To study weaknesses and strengths of hand creams available in the market.

* To identify important attributes of hand cream.

* To obtain consumers' ideal product profile.

* To determine the relationship between various sensory attributes.

5.2 STUDYING WEAKNESSES AND STRENGTHS OF COMPETITIVE PRODUCTS.

Perhaps the best way to maximize consumer acceptance in product optimization is to start with target consumers. Before the product developers decide on the product to be developed they have to gain some information about the existing products; how consumers react to the products already available in the marketplace and also how the new product can compete with those products.

In order to understand how consumers perceive the products in the marketplace, consumer panels can be held using the profile test. The profile test is designed to describe the sensory properties of products in order that quantitative comparisons can be made between samples (Beausire and Earle, 1986).

Consumers test the products against various different attributes using linear scales and also indicate their 'ideal' or 'optimal' score on the scale. The results are used in product optimization.

From the profile of different products on the market, in terms of strengths and weaknesses, the product developers can quickly determine which of the products in the market are well accepted, which are not well accepted, and the reasons underlying acceptance. The product developers can take advantage of the weaknesses of the competitive products, and can provide consumers with acceptable products.

5.3 IMPORTANT ATTRIBUTES

Attributes represent the dimensions along which consumers rate products. The product optimization procedure depends critically on the correct selection of attributes. If the researchers neglect to select proper attributes, then this oversight can invalidate the entire study because the panelists do not evaluate products on the appropriate dimensions in product testing during prototype formulation.

Product developers often evaluate the importance of different attributes to consumers as the key to enhance product acceptability. If the product developers can ascertain what attributes play an important role in consumer acceptance of products, then these attributes provide insights regarding the direction in which to modify products.

Moskowitz (1985 and 1987) has described the methods to measure the importance of attributes to consumers. They are i) direct rating of importance; ii) relative importance measured by 'annoyance rating'; iii) correlation with overall liking; and vi) rate of change of liking with a sensory attribute.

In this study direct rating of importance, correlation with overall liking and rate of change of liking with change in a sensory attribute were used.

5.3.1 Direct Rating of Importance

In direct rating of importance, the researcher simply asks the panelists directly to rate the relative importance of a variety of attributes using a rating scale or a ranking scale. Panelists use a scale to rate how important a role they feel that a characteristic or attribute plays in influencing overall product acceptance or purchase probability (Moskowitz, 1984).

Rabino and Moskowitz (1980) reported that the ranking method was used to measure importance of lotion attributes. The consumers' responses identified four sensory characteristics which consumers felt to be important as indications for an acceptable, efficacious hand lotion - thickness, fragrance or perfume intensity, colour, and the perception of a lotion's ability to soften one's hands.

To analyze the ranking data, the Friedman test is normally used to perform a nonparametric analysis for rank data to determine whether the subjects being studied are significantly different from each other (O'Mahony, 1986; and Meilgaard, 1987b). This method is reasonably accurate for studies involving 12 or more panelists. Multiple comparison procedures for rank data, such as Fisher's LSD (least significant difference) can be used to determine which subjects differ significantly (Meilgaard, 1987b).

Thurstone Case V scaling model can be used to derive an interval scale from ranking judgments (Green et al., 1988). From the scores on a Thurstone scale, it is easy to compare the importance of the sensory attributes to the consumers. In this method the proportions of the total comparisons in which each attribute is considered more important than each of the other attributes are determined. These proportions are then converted to Z values. The Case V program next computes column averages. Finally the lowest scale value is arbitrarily set at zero and other scale values are adjusted as differences from it. The detail of Thurstone Case V scaling is given in Green et al. (1988).

5.3.2 Correlation with Overall Liking

Another method by which the product developer can measure relative importance consists of correlating the rating of overall liking with the liking of a specific attribute. This method requires that the panelists scale a variety of prototypes or in-market products on a series of attributes, including overall acceptance. The researcher then tries to fit a straight-line relationship between purchase probability or overall liking and the attribute level. Those attributes that exhibit a highly linear relation with the criterion measure of acceptance are the more important attributes, whereas those that show low correlations are the less important attributes.

Moskowitz (1984) mentioned that it was possible to measure the strength of the linear relation between each attribute and either overall liking or purchase probability (purchase intent) by calculating the Pearson correlation coefficient (Pearson R). The Pearson R varies from a low of -1 (denoting perfect inverse relation), through 0 (denoting no linear relation at all), and upwards to +1 (denoting a perfect linear relation).

5.3.3 Rate Change of Liking with a Sensory Attribute

'Relative importance of an attribute corresponds to the magnitude of change in acceptance (or other criterion variable) which occurs with unit changes in the independent variable' (Moskowitz, 1985).

From this definition, it is possible to develop a measure of importance for all types of variables; those which show linear relations with acceptance, and those which do not.

From the linear regression between the ratings of overall liking versus the ratings of the attribute, the equation for a straight line relating two variables is generated as:

$$\text{Overall Liking} = A + B(\text{Attribute Rating})$$

From this equation, those attributes showing the steepest linear slope possess the highest importance. In contrast, those attributes showing the shallowest linear slope possess the least importance.

Linear regression which generates a measure of importance by its slope has an advantage over the correlation coefficient. The linear regression approach provides a quantitative measure of the degree to which overall liking changes with attribute change (Moskowitz, 1984).

Some relationships may not be linear, but can be represented by a quadratic equation; in this case the liking increases to a maximum and then decreases at higher levels of the attributes.

5.4 METHOD OF TESTING

This study focused on how the target consumers perceived the hand creams available in the marketplace. Samples of the ten hand creams currently being marketed in New Zealand (detailed in Appendix 5.1) were purchased from supermarket, department store and chemist shop in order to get the samples from different distributors. These samples varied in physical and sensory attributes. Samples (15 g) of the ten hand creams purchased were repackaged in 20 ml glass sample bottles at the laboratory in order to eliminate the brand name and packaging effects.

The twenty consumers used in this test were staff and students in the Technology Faculty, Massey University. The criterion for inviting people to laboratory testing was frequency of hand cream usage (at least twice a week). The consumer respondents group was composed of hand cream users ranging in age from 20 to 50 years old; all of them were New Zealand women.

The 20 consumers were divided into five groups and were invited to the test which lasted between 60 minutes to 75 minutes. When they arrived at the test site, which was a laboratory provided with sinks and water supply, they were asked to wash their hands with 'Lux' liquid detergent, rinse thoroughly with cold water, and dry with the towel, and after a brief interval (about 5 minutes) to proceed with the test. This procedure was intended as a means of bringing all subjects to a common starting point.

Consumers were asked to sit separately at the tables and were randomly presented with six of the ten hand creams, as shown in Table 5.1. They were instructed to score the hand creams using a questionnaire containing a list of product attributes shown in Figure 5.1, one questionnaire per two samples. These attributes were derived from the literature (Schzwartz, 1975 and Stone and Sidel, 1986). Colour and fragrance attributes were not

Table 5.1 Presentation of Hand Creams Samples to the Consumers in Consumer Testing

Panelist	Sample									
	907[a]	251	563	451	682	275	386	738	324	803
1	1[b]	6			2	4	3			5
2	6	5				1	2	3	4	
3	6	1		2			3	4	5	
4	1	2		3		4	5	6		
5	6			5	4	1			2	3
6	4		1	2	6	3			5	
7	5		4	3	1		2		6	
8	5		4		6	3		2		1
9	2		4		6		3		1	5
10		2	1	3	4		6	5		
11		3	4			5	6		2	1
12		6	4		3	2		5		1
13		5	3	4			1	2		6
14		4		2		1		3	6	5
15			2	1	6			3	4	5
16	1		2		4		3	5	6	
17	6			1	2		4		3	5
18		5	6	4		3		1	2	
19	1	5		3		2		4		6
20		2	4		6	5	1			3

<u>NOTE</u>: [a] - brand names for the coded samples are shown in Appendix 5.1.
[b] - order of presentation

HAND CREAMS

I am Hathairat Uaphithak, a Master degree student in Product Development sub-department. I am doing consumer testing on hand cream products in order to get information about reactions of consumers to hand creams available in the marketplace. This information will be used to aid in development of a natural hand cream product.

NAME ______________________ DATE __________

Instructions: You will receive six samples of hand creams. Please evaluate these creams, two at a time, according to the code numbers in the questionnaire.

Dispense an appropriate amount of hand cream on the middle finger of one hand and spread it with three fingers on the back of the other hand, then test another product on the other hand. Between each session wash your hands with the given detergent and dry them properly, then do another session. Rate your reaction to each product and your ideal product on the scales in the questionnaire.

Example:

Viscosity

low ——— 254 X ——— I X ——— 259 X high

TEST SAMPLES _____ _____

PRODUCT ATTRIBUTE

1. PICK UP FROM THE CONTAINER

Thickness

thin ——————————— very thick

Consistency

light ——————————— heavy

2. RUB OUT ON THE HAND

Spreadability

slip easily ——————————— drags

Absorbability

slow ——————————— fast

Time to work in

short ——————————— long

Speed of drying

slow ——————————— fast

3. AFTER FEEL

Coating

not oily ——————————— very oily

Skin appearance/shine

low ——————————— high

Skin feel

dry ——————————— moist

Skin touch

rough, not soft ——————————— very soft

4. OVERALL LIKING

low ——————————— high

Please rank these product attributes according to their relative importance in your opinion.

a. Thickness
b. Consistency
c. Spreadability
d. Absorbability
e. Time to work in
f. Speed of drying
g. Coating
h. Skin appearance
i. Skin feel
j. Skin touch

1. ______________
2. ______________
3. ______________
4. ______________
5. ______________
6. ______________
7. ______________
8. ______________
9. ______________
10. ______________

Figure 5.1 Questionnaire for Hand Cream Consumer Testing included in this testing because these attributes were not studied in the product optimization stage. In this test a linear scale was used, consisting of a horizontal line 15 cm long with word anchors at 1.5 cm from both ends.

Respondents were instructed to use the index finger of one hand to dispense an appropriate amount (one finger tip) of the sample from the container and to spread it with three fingers on the back of the other hand. Respondents scaled their perceptions of the hand creams in terms of various sensory attributes, in order of their occurrence, and overall liking using the linear scale. Table 5.2 shows the definition of the sensory attributes which were used in this study. For each attribute, respondents were also asked to indicate their ideal product in this category (i.e., the ideal hand cream product) using the same set of attributes and scales that they had used to describe the actual product.

Respondents were asked to clean their hands between trials with the given detergent and, after rinsing with cold water, to dry them with the towel. They were asked to rest about 3 to 5 minutes before starting with a new pair of samples. This was to provide a common basis for all subsequent evaluations. They were allowed to reevaluate the samples again if they wanted.

At the end of the test, the respondents were instructed to rank order the attributes used in this study according to their relative importance.

Table 5.2 Definitions of the Attributes Used in Hand Cream Consumer Testing

Thickness (V1)	Perceived denseness of product. Evaluated as force required to squeeze between thumb and forefinger. Rated as thin - very thick.
Consistency (V2)	Perceived structure of product. Evaluated as resistance to deformation and difficulty of lifting from container. Rated as light - heavy.
Spreadability (V3)	Ease of moving product from point of application over rest of hand. Rated as slips easily - drags.
Absorbability (V4)	Rate at which product is perceived to be absorbed into skin. Evaluated by noting changes in the character of product and in amount of product remaining at end of rub out. Rated as slow - fast.
Time to work in (V5)	Time needed to apply product on hand from spreading of the product on the hand until it is thoroughly absorbed. Rated as short - long.
Speed of drying (V6)	Rate at which product dries after applying on hand. Rated as slow - fast.
Coating (V7)	Oiliness of product residual left on hand. Rated as not oily - very oily.
Skin appearance (V8)	The appearance of the skin, evaluated shininess of the skin. Rated as low shine - high shine.
Skin feel (V9)	Changes in skin feel after product application. Evaluated as ability of the cream to moisten the hand. Rated as dry - moist.
Skin touch (V10)	Changes in skin touch after product application. Evaluated as ability to soften the hand. Rated as rough (not soft) - very soft.

To evaluate the results, a grid dividing the 15 cm line into 1 cm units was superimposed on each line; each rating was then assigned a value between 0 and 15. The distance from the left end of the line to the place marked by the subject was measured. The values were then tabulated and used for the statistical computations.

5.5 ANALYSIS OF RESULTS

5.5.1 Direct Rating of Importance of Product Attributes

The first analysis of importance of hand cream sensory attributes was rank data analysis. The results from consumers' ranking of relative important attributes are shown in Table 5.3.

Table 5.3 Consumers' Ranking of Relative Importance of Hand Cream Attributes

Panelist	Thick	Consis	Spread	Absorb	Time	Speed	Coat	Skin appear	Skin feel	Skin touch
1	10	9	8	6	3	5	4	2	1	7
2	10	9	1	2	3	4	5	6	7	8
3	9	10	8	1	5	7	6	4	3	2
4	7	3	9	4	6	1	10	8	2	5
5	6	5	8	7	1	9	4	10	2	3
6	10	9	4	2	1	3	5	6	7	8
7	8	5	9	2	6	3	7	10	1	4
8	5	7	1	2	4	3	9	10	8	6
9	8	9	7	4	1	2	6	10	3	5
10	4	10	7	1	8	5	6	9	3	2
11	7	8	6	1	4	5	9	10	3	2
12	7	5	6	3	4	9	10	1	8	2
13	9	10	8	2	1	3	4	7	5	6
14	9	8	7	1	2	6	5	10	3	4
15	9	10	7	1	5	6	8	3	2	4
16	2	8	3	4	5	7	6	10	1	9
17	9	10	8	5	6	7	2	4	1	3
18	7	10	6	3	8	9	2	5	1	4
19	10	9	7	5	4	6	8	3	1	2
20	9	10	8	5	6	7	3	4	1	2
R	155	164	128	61	83	107	119	132	63	88
R^2	24025	26896	16384	3721	6889	11449	14161	17424	3969	7744

NOTE: R = Rank total of each attribute

The Friedman test was used to determine whether the difference of importance between attributes were significant or not (O'Mahony, 1986). Chi-square value was calculate using the following formula:

$$\chi_r^2 = \frac{12}{Nk(k+1)} \sum (R^2) - 3N(k+1)$$

where R = rank total of each attribute

N = number of subjects

k = number of attributes

Hence,

$$\chi_r^2 = \frac{12}{(20)(10)(10+1)}(155^2 + 164^2 + ... + 88^2) - (3)(20)(10+1)$$

$$= 63.39$$

χ^2-table was used to test whether this value of χ_r^2 indicated that there were differences in relative importance of the ten sensory attributes. For degree of freedom = 10-1 = 9, χ^2 = 27.88 at p = 0.001. Since χ_r^2 (63.39) was greater than χ^2 from the table, there was significant differences in relative importance of the sensory attributes being studied.

To determine which attributes were significantly different in relative importance, the critical value of the multiple comparison was calculated as:

$$LSD_{rank} = z_{\alpha/2}\sqrt{Nk(k+1)/6}$$

$$LSD_{rank} = 1.96\sqrt{20(10)(11)/6}$$

$$= 37.53$$

Any two samples whose rank sums differed by more than LSD_{rank} = 37.53 are significantly different at the 5% level. Figure 5.2 shows grouping of the sensory attributes of hand cream products, attributes which are on the same line are not significantly different in terms of relative importance. It was concluded that absorbability, skin feel, time to work in and skin touch were not significantly different in terms of importance according to the consumers' opinion. Time to work in, skin touch, speed of drying and coating also had no difference in relative importance. As these attributes were ranked in the high order, so they were regarded as important attributes by the consumers.

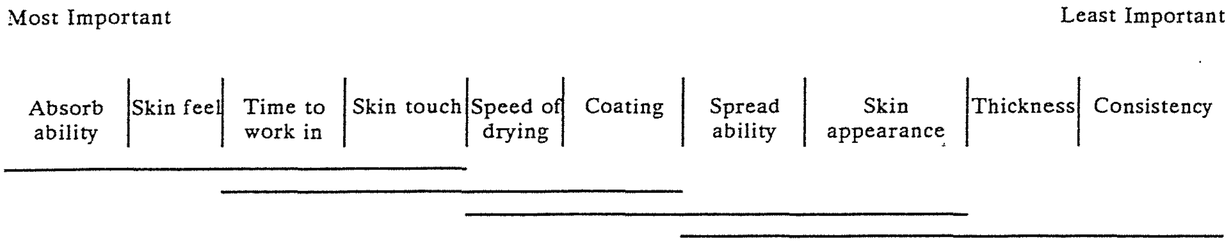

Figure 5.2 Grouping of Sensory Attributes in Terms of Relative Importance

The ranking scores were changed to scores on an interval scale by using Thurstone Case V scaling model (Green et al., 1988) to analyze the data, the results are shown in Table A5.1 and Table A5.2 in Appendix 5.2. Final scale values are shown in Figure 5.3. From the scale value of attribute 1 through 10 it can be seen that 'absorbability', receives the highest scale value followed by 'skin touch', 'time to work in', and 'skin touch'.

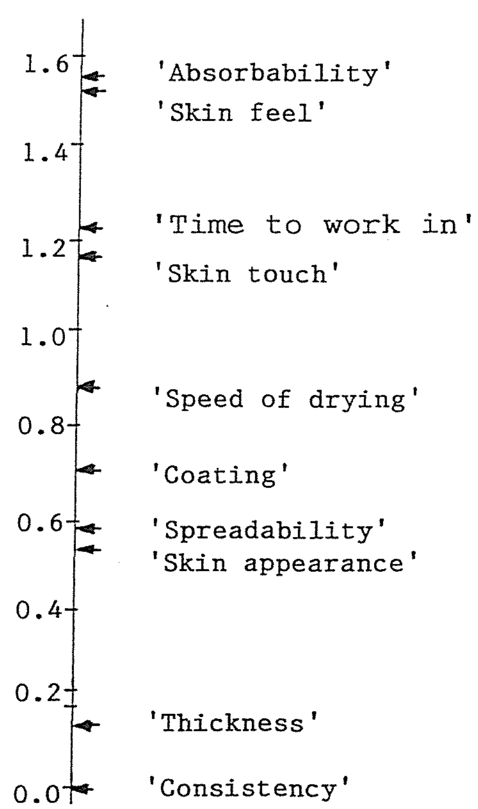

Figure 5.3 Interval Scale Derived from Thurstone Case V Scale for Importance of Hand Cream Attributes

5.5.2 Correlation of Attribute Rating with Overall Liking

From the individual consumers' scores for each attribute the mean scores and the standard deviations were determined for each product. The means of consumers' scores as shown in Table A5.3 (Appendix 5.3). The means of ideal ratio scores (sample mean score/ consumer mean ideal score) obtained are shown in Table A5.4 (Appendix 5.3).

The second analysis for importance of hand cream attributes consisted of the correlation between overall liking and each attribute. To do this, the mean scores of all of the samples for each attribute, were correlated with the mean scores for overall liking. Table 5.4 shows correlation between each attribute in this study.

Table 5.4 Correlation between Overall Liking and Each Hand Cream Sensory Attribute

Attribute	Correlation with Overall Liking
Time to work in	-0.793*
Speed of drying	0.700*
Absorbability	0.640*
Consistency	-0.553
Spreadability	-0.510
Thickness	-0.509
Coating	-0.501
Skin touch	-0.283
Skin feel	0.098
Skin appearance	0.034

NOTE: * - significant at $0.05 \geq p \geq 0.01$

From correlation of attribute rating with overall liking, it can be seen that time to work in had the highest correlation with overall liking followed by speed of drying and absorbability. No other correlations were significant at $0.05 \geq p \geq 0.01$. Liking decreased with increasing time to work in, and increased with faster drying and faster rate of absorption.

Using the mean attribute scores for the ten hand creams, correlation value between each pair of sensory attributes were determined. They are shown in Table 5.5.

Table 5.5 Correlation Values between Sensory Attributes of Hand Creams.

	Thick	Consis	Spread	Absorb	Time	Speed	Coat	Skin appear	Skin feel
Consis	0.966**								
Spread	0.900**	0.942**							
Absorb	0.015	0.011	0.153						
Time	0.328	0.314	0.174	-.909**					
Speed	-.346	-.445	-.418	0.648*	-.660*				
Coat	0.521	0.623	0.546	-.384	0.418	-.696*			
Skin appear	0.470	0.491	0.494	0.156	-.061	-.280	0.691*		
Skin feel	0.059	0.151	0.027	-.153	0.053	-.271	0.616	0.474	
Skin touch	0.504	0.504	0.675*	-.024	0.101	-.590	0.617	0.419	0.117

NOTE: * = significant at $0.05 \geq p \geq 0.01$
** = significant at $p \leq 0.01$

From the correlation values, the thickness and consistency attributes were correlated to each other at significance level $p \leq 0.01$. Absorbability correlated to time to work in and speed of drying at significant level $p \leq 0.01$ and $0.05 \geq p \geq 0.01$ respectively. Hence, to eliminate using attributes which have the same meaning to the consumer and to reduce the number of attributes to be used in sensory testing, consistency was used to represent thickness, absorbability to represent time to work in and speed of drying attributes. Although there were still some other attributes which of drying attributes. Although there were still some other attributes which were correlated with each other, such as thickness and consistency with spreadability, spreadability was not replaced with consistency because they were not in the same category in hand cream attributes.

5.5.3 Relative Importance by Linear Equations Between Attribute Level and Overall Liking

The third analysis consisted of developing straight line relations between overall liking and the level of each attribute. The straight line equations which exhibit $R^2 \geq .40$ are shown in Table 5.6.

Table 5.6 Linear Equations Relating Sensory Rating to Overall Liking[a].

Attribute	Intercept	Attribute Level	R^2
Time to work in	12.311	-0.690 (-3.68)[**b]	.63
Speed of drying	3.522	0.536 (2.78)[*]	.49
Absorbability	4.462	0.423 (2.36)[*]	.41

NOTE:
[a] - Only equations with $R^2 \geq .40$
[b] - t-values appear in parentheses
[*] - significant at $0.05 \geq p \geq 0.01$
[**] - significant at $p \leq 0.01$

From the slope of the straight line relationships between overall liking and level of each attribute, time to work in exhibited the highest slope value followed by speed of drying and absorbability.

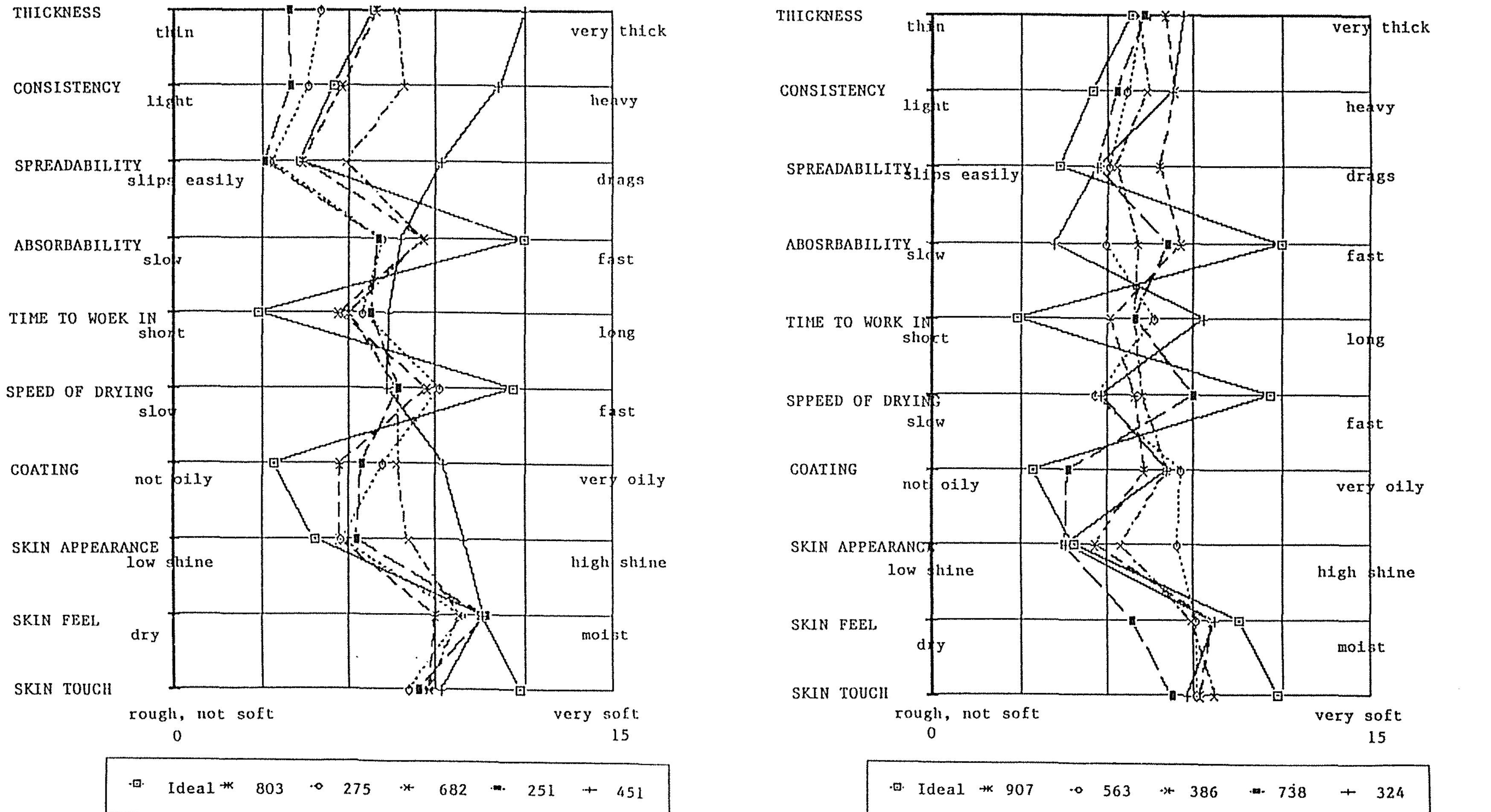

Figure 5.4 Sensory Product Profiles of Product Samples and Ideal Product of Consumer Test

5.5.4 Product Profile

The product profiles of the ten hand cream products derived from the mean attribute scores of the consumer testing and the consumers' ideal product profile, are shown in Figure 5.4. No single product delivered exactly the attributes' levels at which the ideal product was located. From the product profile, none of the products used in this study had a position near the ideal product in terms of absorbability, time to work in, speed of drying, coating and skin touch most of which were classified by the consumers as important attributes, even the product which got the highest score for overall liking. Hence, in developing a new hand cream product, these sensory attributes were considered in order to obtain the product which will be accepted by the consumers and can compete with the existing products.

5.6 DISCUSSION AND CONCLUSION

Table 5.7 shows the summary of the most important hand cream sensory attributes obtained from the consumer testing using the three methods of importance measure.

Table 5.7 Summary of Order of Importance of Hand Cream Sensory Attributes Derived from Three Importance measurements

Importance Rating		Correlation		Overall liking = A + B(Attribute level)	
Absorbability	(1.55)[a]	Time to work in	(-0.79)[b]	Time to work in	(-0.69)[c]
Skin feel	(1.52)	Speed of drying	(0.70)	Speed of drying	(0.54)
Time to work in	(1.23)	Absorbability	(0.64)	Absorbability	(0.42)
Skin touch	(1.17)	Consistency	(0.55)	-	-

NOTE:
[a] - Thurstone scale value
[b] - Correlation value
[c] - Slope of the straight line

Although skin feel attribute was ranked highly by the consumers in the direct rating, as shown in Table 5.7, it was not identified as an important attribute when either correlated or regressed against overall liking. From this information it can be concluded that these consumers did not actually use this attribute in making decisions about product acceptance.

Direct rating uses the panelist's opinion to determine the degree of importance. Panelists use their own attitudes to generate the ranking. It is not possible to know whether these important attributes, as identified by the consumers, really drive acceptance in actual behaviour. What panelists say about importance may not correspond to actual behaviour. However, collection of information about importance of attributes from a group of consumers is easy to manage, to analyze the results and less expensive when compare with the other two methods.

In correlations of attribute ratings with overall liking, this procedure discovers the statistical relation between two subjective variables, both rated by the consumer. Consumer panelists do not need to reflect on their attitudes. The data can be analyzed and the results are used to evaluate the degree to which the overall liking correlates to the attribute being studied. A problem may occur in using this method owing to selection of the samples used to measure attribute ratings and overall liking. If a wide range of products is selected, it is possible to conclude that a strong relation exists between attribute level and overall liking or not. On the other hand, by selecting a narrower range of products, and correlating overall liking with attribute level, it might be concluded that the attribute has little importance at all, as a results of low correlation coefficient.

The linear regression which generates a measure of importance by its slope has an advantage over the correlation coefficient. The linear regression approach provides a quantitative measure of the degree to which overall liking changes with attribute change. If there does exist a significant linear relation between attribute level and overall liking, for a variety of measures, then the linear slope can differentiate among the attributes, all of which may show equally high correlation. In contrast, the correlation coefficient limits itself strictly to the strength of a linear relation, but not to the quantitative nature of that linear relation. However, relationships may not be linear but liking may increase to a maximum with an attribute and then decrease; or may stay at the same value before decreasing.

Consumers' ideal product profile obtained from this study, was used in product optimization to generate the upper and lower limits for the linear programming model.

From the product profile, there were differences between the products, primarily with the attributes of thickness, consistency, coating, and skin appearance. The product (coded 803, Boots Light Moisturizing Cream) which was assigned the highest overall liking score by the consumer, was used in comparisons with the products which were developed in further experiments. Hence, it could be indicated that the developed product was able to compete with the product already in the market or not.

In some cases from the product profile, competitive product attributes were not in the position near the ideal product on the product profile because these attributes were not important for the consumer acceptability and to obtain the acceptable level of these attributes it may make the level of other attributes not acceptable or increase the cost of production. So the competitors do not produce the product which it is positioned near the ideal product on all attributes. Hence, the attribute importance measurement helps the formulator to come to the conclusion whether to use the attributes which are found to be the weakness of the competitor to be the key for developing a new product or not.

From this study it was found that absorbability, skin feel, time to work in, and skin touch, were important attributes according to the consumers. The overall liking assigned to a hand cream was directly related to its perceived ability to be absorbed into skin. None of the existing products was rated highly on these important attributes Hence, formulation efforts had to be focused on these attributes in order to maximize consumer acceptance.

For further experiments, absorbability which represents the ability to be absorbed into skin, as it was highly correlated with time to work in and speed of drying, was regarded as the most important attribute and was used to identify the optimal product. However, other attributes: consistency, spreadability, coating, skin appearance, skin feel and skin touch were also included in the studies in order that the developed product could also be compared in terms of these attributes.

CHAPTER 6

PANEL TRAINING

The aim of this panel training was to obtain a trained panel to be used in hand cream sensory testing during product optimization. This panel was used through the product optimization process.

In this study, panel training was composed of 3 important tasks: selection, testing, training, of panelists. In selection of panelists, the ability to discriminate the products which had different levels of some attributes was assessed. Panelists were tested before training so that the panel leader could anticipate whether the method of testing and the scoresheet used in the test needed to be changed or not. In panel training, panelists were trained in order to be familiar with the test procedures, the descriptive terms and to improve their ability to recognize and identify product attributes.

6.1 PANEL SELECTION

In the selection session, each candidate's capabilities and personal criteria, as shown below, were determined:

* The ability to detect differences in attributes present and in their intensities.
* The ability to describe those attributes using descriptive terms for the attributes and scaling methods for the differences in intensity.
* Interest in full participation in the training, practice and ongoing work phases of a train panel.
* Availability to participate in all phases of the panel's work.

* General good health and no illnesses related to the sensory properties being measured such as: skin easily allergic to any chemical substance, central nervous system disorders, inability to identify the skin feel.

In this study, candidates who were 15 Thai students studying at Massey University were invited to attend the panelist selecting session. These candidates were those who were interested in participating in the sensory project and were available for sensory testing when needed. All of them had never been trained for skin care sensory testing although some of them had some experience on food product sensory testing.

Thai students were chosen to be the trained panel instead of New Zealanders because of the availability of the panelists to participate in all the panel's work. The selected panelists were trained for scaling the product sensory attributes, they did not provide measures of preference or ideal product profiles in the test. In addition, no measure of importance was assigned to any of the attributes. Both ideal product profile and attribute importance information were derived from testing with consumers only.

6.1.1 Method of selection

The triangle test was used to select panelists who had ability to discriminate products. Panelists were given sets of three coded samples. They were instructed that two samples were identical and one was different (or odd). Then they were asked to test each sample from left to right and select the odd sample.

In order to economize in the number of evaluations required to draw a conclusion on acceptance and rejection of a trainee on a panel, sequential triangle tests were used. Sequential tests are very practical and efficient because they take into consideration the possibility that the evidence derived from the first few evaluations may be quite sufficient (for fixed values of α and β) to draw a conclusion (Meilgaard et al. 1987a).

In this method a sequence of evaluations were conducted and the results of each completed test were entered into a graph in which three regions were identified: the acceptance region, the rejection region, and the continue-testing region. Then the number of trials was plotted on the horizontal (x) axis and the total number of correct responses was plotted on the vertical (y) axis. The result of the first test, if correct, was entered as (x,y) = (1,1) and if incorrect, as (x,y) = (1,0); for each succeeding test, increased x by 1, and increased y by 1 for a correct reply and by 0 for an incorrect reply. Testing was continued until a point touched or crossed one of the lines bordering the region of indecision. Then the conclusion to reject or accept the panelist was made. Figure 6.1 shows the graph of the sequential approach for selection of panel trainees by triangle test used in this study.

The equations of the two lines that from the boundaries of the acceptance, rejection, and continue-testing regions in Figure 6.1 are:

Lower line: $$d_0 = \frac{\log\beta - \log(1-\alpha) - n.\log(1-p_1) + n.\log(1-p_0)}{\log p_1 - \log p_0 - \log(1-p_1) + \log(1-p_0)}$$

Upper line: $$d_1 = \frac{\log(1-\beta) - \log\alpha - n.\log(1-p_1) + n.\log(1-p_0)}{\log p_1 - \log p_0 - \log(1-p_1) + \log(1-p_0)}$$

α - is the probability of selecting an unacceptable trainee

β - is the probability of rejecting an acceptable trainee

p_0 - is the maximum unacceptable ability (measured as the proportion of correct answers)

p_1 - is the minimum acceptable ability (measured as the proportion of

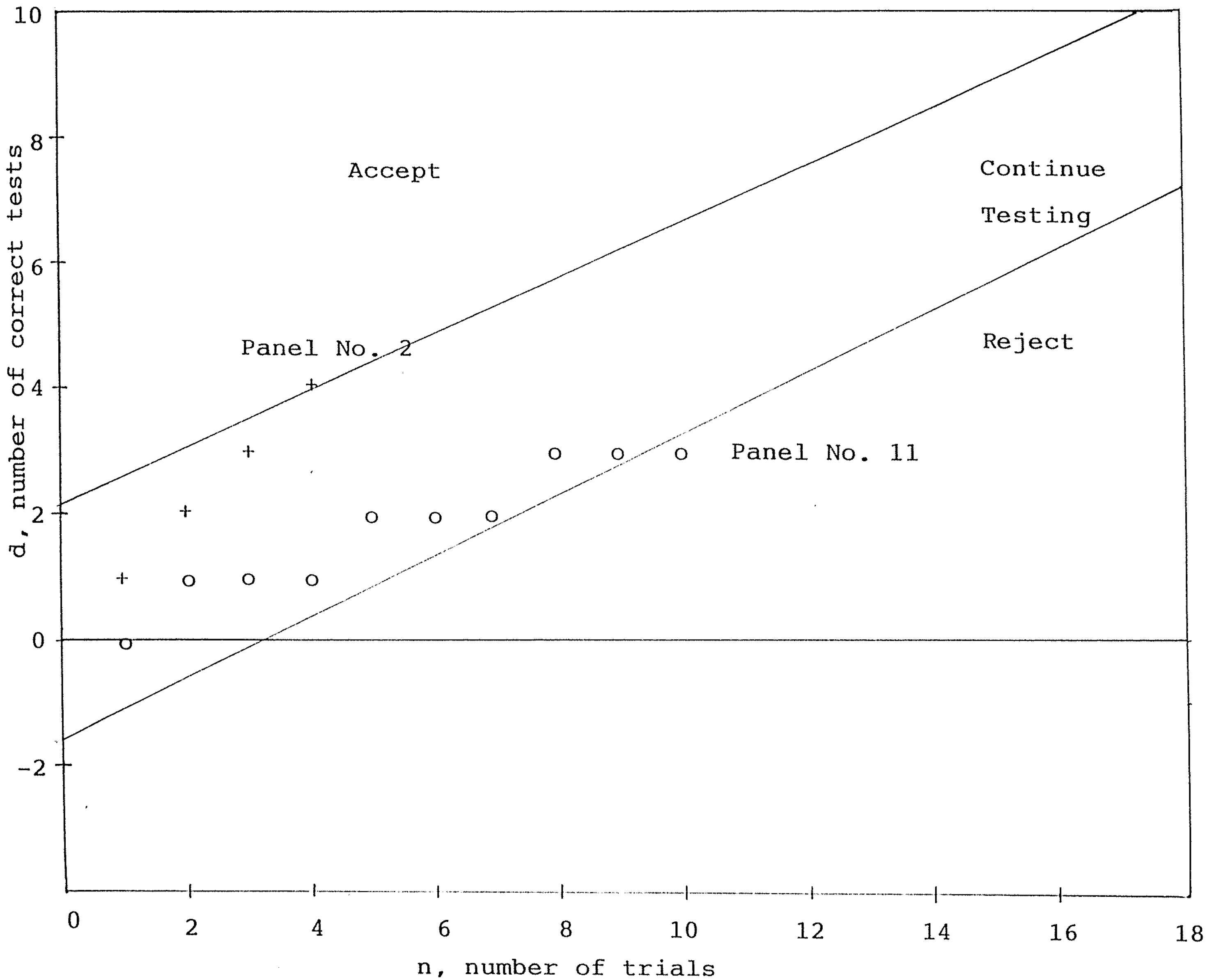

Figure 6.1 Sequential Approach for Selection of Panelists by Triangle Test

correct answers)

Parameters in this test are:

$\alpha = 0.05$ $\beta = 0.10$

$p_0 = 0.333$ $p_1 = 0.66$

6.1.2 Sample Preparation

Samples used in this test were obtained from the preliminary experiment in Chapter 4, as mentioned in Section 4.7. A four-pair hand cream sample set, was tested by the subjects. Samples in each pair were chosen so that they were different in some sensory attributes, such as consistency, absorbability, shine etc. 15 g of each sample was placed in a 20 ml sample bottle and was coded with a three digit random number. Each sample in one pair had equal opportunity to appear in the test as the odd sample and as the identical sample. The samples were randomly presented to the subjects in the form of a triangle test. Figure 6.2 shows the worksheet for this session.

Date 6/08/90 **WORKSHEET** **Test code** TA-PS 90/1

Type of samples: Hand Creams
Type of test: Triangle Test

Sample identifications[a]	Code	
A: Lab code R-1	301	411
B: Lab code R-8	543	345
C: Lab code R-1	443	349
D: Lab code F-2	631	451
E: Lab code F-1	711	921
F: Lab code R-7	742	542
G: Lab code F-3	821	831
H: Lab code R-6	842	849

Code serving containers as follows:

Panelist# 1,5, 9,13	2,6, 10,14	3,7, 11,15	4,8, 12	Order of presentation
	Trial No.			
1	1	8	10	A B B (301,543,345)
2	9	11	9	C C D (443,349,631)
3	10	9	8	E E F (711,921,742)
4	1	12	1	G H H (821,842,849)
5	11	14	10	E F F (711,742,542)
6	2	8	11	B A A (345,301,411)
7	12	7	7	D C D (631,921,451)
8	3	13	2	F E F (742,921,542)
9	13	6	13	H G G (842,821,831)
10	14	5	16	A A B (301,411,345)
11	4	15	6	C D D (443,631,451)
12	5	4	3	E E F (711,921,542)
13	15	3	14	G G H (821,831,849)
14	6	16	15	A B A (301,543,411)
15	16	2	4	C D C (443,631,349)
16	7	1	5	E F E (711,542,921)

NOTE: [a] - See Section 4.7 for descriptions these hand cream samples.

FIGURE 6.2 Worksheet for Sequential Triangle Test Used in Panel Selection.

6.1.3 Test Procedure

A subject had to test the sets of three samples and select the odd sample. Figure 6.3 is the scoresheet used in this test. As the subject completed one test, the result was added to previous responses, and the cumulative results were entered in Figure 6.1. The test series continued until the subject was either accepted or rejected.

TRIANGLE TEST

NAME ______________________ DATE __________

TYPE OF SAMPLE ______________________

INSTRUCTIONS
You will receive three coded samples, two are the same and one is different. Evaluate samples from left to right and determine which sample is different from the other two.

You may re-evaluate the samples. You must make a choice. Thank you.

Set of three samples	Which is the odd sample?	Comments
____ ____ ____	______	__________________

Figure 6.3 Scoresheet for Sequential Triangle Test.

6.1.4 Analysis of Results

The number of correct identifications made by each candidate is shown in Table 6.1.

TABLE 6.1 Accumulative Number of Correct Answers Obtained from Each Panel in Panel Selection by Triangle Test.

	Number of trials										
Panelist	1	2	3	4	5	6	7	8	9	10	
1	0	1	2	2	3	4	5	6	Ac		
2	1	2	3	4	Ac						
3	1	2	3	3	4	5	Ac				
4	0	1	1	2	3	4	5	5	6	7	Ac
5	0	1	2	3	4	5	Ac				
6	1	2	3	4	Ac						
7	1	2	3	3	3	4	5	6	Ac		
8	1	2	3	4	5	Ac					
9	1	2	3	3	4	5	Ac				
10	1	2	3	4	Ac						
11	0	1	1	1	2	2	2	3	3	3	Re
12	1	2	3	4	Ac						
13	1	1	2	3	4	5	Ac				
14	1	2	2	3	4	5	Ac				
15	1	2	3	4	Ac						

NOTE: Ac = Accept
Re = Reject

From the sequential triangle test, only one subject (panelist number 11) was rejected. The other subjects were asked to attend the training session for hand cream sensory testing and were used in further studies.

6.2 TESTING OF SELECTED PANELISTS

Twelve from the 14 selected panelists were asked to participate in this panel testing session, since the other two were not available. Panelists were divided into two groups so that it was easy to manage the panel. This session enabled the panelists to familiarise themselves with samples, method of testing and the terms used to describe the product. The results from this session was used to improve the product testing procedure which included scoresheet, number of samples, descriptive terms, scale etc.

6.2.1 Scale

The scale used in this study was a linear scale which had been found to be effective for quantitative sensory profiling (Stone et al., 1974). A 15cm long linear scale with anchor at 1.5 cm from both ends was used. Panelists were asked to mark on the scale at the position they thought appropriate for the attribute of the samples.

6.2.2 Terms for Product Attributes

Descriptive terms for product attributes used in this study were selected from those used in the consumer testing in Chapter 5. They were consistency, spreadability, absorbability, coating, skin appearance, skin feel and skin touch. These terms appear in the questionnaire in Figure 6.4. The panel leader described the definition of each term to the panelists at the beginning of the test.

6.2.3 Sample Preparation

Six products were used in this test. Two were selected from the commercial products used in the consumer testing session and four from the preliminary formula selection experiment in Chapter 4, as mentioned in Section 4.7. Samples were selected in order to get a wide variation of sensory attributes among the samples. These samples were placed in a 20 ml plastic container in order to eliminate packaging and brand name effects, then they were coded with three digit random numbers. Viscosities of these samples were measured by Ferranti-Shirley viscometer, the results are shown in Table 6.2.

HAND CREAMS

NAME ______________________________ DATE ____________

Instructions: You will receive six samples of hand creams. Please evaluate these creams, two at a time, according to the code number in the questionnaire.

Dispense an appropriate amount of hand cream on the middle finger of one hand and spread it with three fingers on the back of the other hand, then test another product on the other hand. Between each session wash your hands with the given detergent and dry them properly, then do another session. Rate your reaction to each product on the scales in the questionnaire.

Example:

Thickness

254 345 259

low ——————————————— high

PRODUCT SAMPLES _____ _____

PRODUCT ATTRIBUTE

1. PICK UP FROM THE CONTAINER

Consistency

light ——————————————— heavy

2. RUB OUT ON THE HAND

Spreadability

slips easily ——————————————— drags

Absorbability

slow ——————————————— fast

3. AFTER FEEL

Coating

not oily ——————————————— very oily

Skin appearance

low shine ——————————————— high shine

Skin feel

dry ——————————————— moist

Skin touch

rough, not soft ——————————————— very soft

Figure 6.4 Questionnaire for Panel Testing

Table 6.2 Viscosities of Samples Used in Panelist Testing

Sample	Viscosity (poise)
452	2.01
307	2.15
803	5.65
726	6.22
569	8.32
451	21.82

6.2.4 Testing Procedure

This session was important for establishing the routine which was followed in later sessions. Before the test, the panelists were given an orientation on the sensory testing method. Each panelist was asked to read the instructions in the questionnaire before performing the test. The meaning of each sensory attribute term in the questionnaire was explained to each panelist so that any error in panel interpretation could be avoided. If any panelist did not fully understand any sensory attribute term, it was explained until that term was clearly perceived. Panelists were instructed to score every sample on the same scoresheet.

In general, any kind of laboratory sensory tests is performed in a room which is partitioned into separate booths, in order to avoid subject-to-subject influences. In this study, however, this kind of room was not available and also, in the test, sinks and water supply were needed so that a laboratory room was used. Sinks and water supply for panelists to wash their hands were located in this room and the pathway was wide enough to avoid any disturbance. Lighting for the testing area was uniform and provided by daylight fluorescent lamps so that panelists could perceive the changing of skin appearance. The panelists were asked to sit separately during sample evaluation.

Samples were randomly presented to the panelists, two samples at a time, as shown in Table 6.3. Panelists were instructed to evaluate the product in the same way that they would evaluate the samples in the following experiments. Firstly, panelists washed their hands with a 'Lux' liquid detergent, rinsed thoroughly with cold water and dried their hands with the given towel. After a brief interval (5 minutes), they proceeded with the test.

TABLE 6.3 Serving Order for Hand Cream Panel Testing

Panelist	Order					
	1	2	3	4	5	6
1	803	451	307	452	569	726
2	307	452	451	569	726	803
3	451	803	726	569	452	307
4	452	803	569	726	307	451
5	726	451	452	569	307	803
6	307	452	803	451	569	726
7	569	307	452	451	726	803
8	569	726	452	803	451	307
9	803	726	569	451	307	452
10	452	726	307	451	803	569
11	726	451	307	803	569	452
12	307	569	452	451	726	803

Subjects were instructed to take an appropriate amount of sample (one finger tip) from the container using the index finger. While lifting the sample from the container they were asked to evaluate the consistency of the product. Then they spread hand cream on the back of the other hand with the middle three fingers. The panelists evaluated the characteristics of the product in order of occurrence, starting with pick up (consistency), rub out (spreadability and absorbability) and then after the product was absorbed into the skin, followed by after feel (coating, skin appearance, skin feel and skin touch). The panelists made a mark across the linear scale at the point which represented what they perceived. They were asked to wash their hands, as they did at the beginning of the test, and wait for 3 to 5 minutes before testing new samples.

After the testing finished, panelists attended a group discussion in order to discuss the test. The panel leader urged the panelists to express their opinions on the terms used in this test, number of samples, number of product attributes, scale, etc.

6.2.5 Analysis of results

Results from panel testing are shown in Appendix 6.1. The analysis of variance model was used to analyze these results. Results of analysis of variance are shown in Table 6.4.

Table 6.4 Summary of Analysis of variance

Attribute	Panel F-value	Sig. level	Sample F-value	Sig. level
Consistency	2.63**	0.01	10.42**	0.01
Spreadability	2.05*	0.05	4.82**	0.00
Absorbability	1.27	0.27	0.25	0.94
Coating	0.73	0.69	3.24**	0.01
Skin appearance	1.45	0.19	3.67**	0.01
Skin feel	7.37***	0.00	4.36**	0.00
Skin touch	5.93***	0.00	3.31**	0.01

NOTE: * - significant at $0.05 \geq p \geq 0.01$
** - significant at $0.01 \geq p \geq 0.001$
*** - significant at $p \leq 0.001$

From the results of ANOVA in Table 6.4, it can be seen that the significance level of F-ratio of panelists for thickness, consistency, spreadability, skin feel and skin touch were less than 0.05. Therefore, panelists had significant difference in evaluating thickness, consistency, spreadability, skin feel and skin touch. And the significant level of F-ratio of samples for absorbability was more than 0.05 so it was concluded that they could not identify the difference of absorbability between samples.

In this testing session, panelists gave the following comments during group discussion:

* There were too many samples in the test.
* Panelists had difficulty in using the unstructured scale, they preferred a scale with numbers on it.
* Some panelists could not understand some terms used to describe samples, such as: skin feel, skin touch, and slip and drag, which were used to describe the spreadability attribute.
* Some panelists preferred to evaluate every product at the same time to make it easier to compare the difference of attributes between samples.
* Some panelists complained that the scale was too long.

In planning the further training sessions the following points had to be noted:

* Numbers of samples used in each session should be decreased.
* The words which were used to describe some attributes needed to be altered in order to make panelists understand them better.
* Panelists should evaluate the samples and then show their individuals scores to the group to compare the score together.
* Panelists were urged to use the whole scale not only some part of the scale.

6.3 TRAINING OF PANELISTS

Panelists were invited to the training sessions, each training session lasted from one to one and a half hours. The panel was divided into two groups, with six panelists in each group, to make it easy for the panel leader to manage and the panelists could come in the session that suited them. The training were usually performed between 1.00-2.30 p.m. or 3.00-4.30, the times which suited most panelists.

6.3.1 Scale

From panel testing, panelists had difficulty in using the linear scale with anchors only at both ends. Hence in panel training, a third anchor at the mid point was added to the scale. In this training, a semi-structured linear scale with 2 anchors at 1.5cm from each end and the third anchor at the midpoint was used. Some of the words which were used to describe the product attributes on the scale were altered to make it easier for panelists to understand. The anchors moved from left to right with increasing intensity; weak to medium to strong.

During training in the use of the scale, numbers were not discussed and panelists were not told that the scale had numerical content so they did not make any attempt to put their own numbers on the scale which might cause confusion.

6.3.2 Terms for Product Attributes

In the training session, the terms which were used to describe product attributes were derived from those used in consumer testing so the panelists did not have to develop the descriptive terms. However, they had to understand the definition of the descriptive terms used in this study.

HAND CREAM SENSORY TESTING

NAME ______________________ DATE __________

Instructions: You will receive a number of hand cream samples. Please evaluate these creams according to the given order.

METHOD

Take an appropriate amount of hand cream from the container with the index finger of one hand. While lifting the finger out of the container, evaluate the consistency of the sample. Spread it with three fingers over the back of the other hand, then test another sample on the other hand. Between each session wash your hands with the given detergent and dry them properly, then do another session. Rate your reaction to each product on the scales in the questionnaire by placing a mark across the line at the point which represents what you perceive.

Example:

Thickness

254 345 259

low medium high

PRODUCT SAMPLES _____ _____ _____

PRODUCT ATTRIBUTE

1.PICK UP

Consistency

light medium heavy

2. RUB OUT

Spreadability

slip easily moderately easy drags

Absorbability

slow moderate fast

3. AFTER FEEL

Oiliness

not oily medium very oily

Shine

low medium high

Stickiness

not sticky moderately sticky very sticky

Moistness

not moist medium very moist

Softness

not soft medium very soft

Figure 6.5 Questionnaire for Panel Training

Some terms were changed in order to make it easy for the panelists to understand. Coating was changed to oiliness; skin appearance to shine; skin feel to moistness; and skin touch to softness. Stickiness was added in the scoresheet because the panelists could detect this attribute during the test. The scoresheet which was used in the training session is shown in Figure 6.5.

6.3.3 Sample Preparation

The number of tested products was decreased to 3 products because of the results from panelist testing, therefore the panelist would not be bored with the long session and any 'fatigue effect' would be avoided.

In the three samples which were used in this session, two were commercial products (803 and 451), and one prototype from the preliminary experiment (307). See section 4.7 for details. They varied in many sensory attributes so that the panelists could experience what constituted the extremes in intensities for many of the terms. These samples were prepared as described in section 6.2.3.

6.3.4 Training Method

The definitions of terms were given at the beginning of the training session to enable the panelists to understand the meaning of the descriptive terms being studied. As the panelists were working with the various attributes terms, the group might develop their own meaning of the descriptive terms which were more concise and easier for them to understand and were accepted by the members of the group. The panel leader then took the ideas of the group and expressed them in a clear, concise statement, and always checked back with the group to see if that was what was really meant by the term.

The panelists were asked to test the samples as described in panel testing (section 6.2.4) and rate their perception of each attribute on the scale in the scoresheet.

The panel was trained three times in order to obtain a precision on sensory testing. Each session lasted from one to one and a half hours. At the beginning of the second and the third training sessions, the panelists were given their results of the former training session and were informed if their results were significantly different from other panelists. The panel leader also motivated the panelists to use the whole scale, if from the results, they used only some part of the scale.

For the first training, the panelists evaluated the samples in an open session so they could compare their scores with other members in the group for each attribute and they could ask about the terms which were used to describe product sensory attributes and the test procedure.

During the training, the panel leader checked whether all panelists were perceiving the product in a similar manner, by asking each panelist if she perceived the product in the first, second, third or fourth quarter of the linear scale. This indicated to both panel leader and panelists the degree of similarity in perception of the panel. This technique also revealed the panelist who was seeing things very differently from the group. The panelists were allowed to test the sample again and could change their scores if they wanted.

In the second training four samples were used. However, it was found that, when panelists tested more than three samples the results were significantly different between panelists so it was suggested that they should not be asked to test more than 3 samples in one session because they were becoming tired and bored and it was not possible to get a good result.

In the third training only three samples were used. The panelists tested products individually so they could concentrate on the testing.

6.4 RESULTS AND DISCUSSION

The scores of each panelist were analyzed using ANOVA, mean scores and standard deviations were determined. The results are shown in Appendix 6.2. The analysis of variance of panelists scores are shown in Table 6.5.

The analysis of variance was used to show whether the panelists were significantly different in testing the samples and whether the panelists were able to identify the difference in sensory attributes between samples.

Panel's ability to distinguish between products was examined by means of an ANOVA on a scale-by-scale basis. The magnitude of the difference between products was reflected in an F-ratio and its corresponding probability value or significance level.

From the results of the first training, the significant level of F-ratio of samples for absorbability (.06), and softness (.24) attributes were more than 0.05. It can be said that panelists could not identify the difference in terms of absorbability and softness between the samples.

In the second training, the significant level of F-ratio of samples for absorbability (0.39), moistness (0.60), and softness (0.84) attributes were more than 0.05. Hence, in this testing, the panel could not identify the difference in terms of absorbability, moistness and softness between the samples.

In the third training, the panel could identify the difference of every attributes between samples except absorbability in which the F-ratio of samples was 0.14.

There was no significant difference between panelists after the third training (the significant level of the F-ratio of every attributes for panelists are more than 0.05). Therefore, it can be said that there were no significant differences between panelists in sample evaluation.

6.5 CONCLUSION

Although the panel was not good enough in its performance on one attribute and further training was needed, this panel was used in product testing without any more training because of the limitation of time. However, if good training samples are presented enough times, the panel's performance would be more consistent in sample evaluation.

From this training, it can be said that panelists who had no experience in sensory testing can be trained to test the products by quantitative sensory profiling method.

The panel obtained from this training was used for sample testing which will be discussed in the next chapter.

CHAPTER 7

EXPERIMENTAL DESIGN

The aim of this experimental design was to obtain the linear empirical equations showing the relationships between the hand cream ingredients and the sensory attributes of the product. These relationships were used in the product optimization using linear programming.

7.1 INTRODUCTION

After the selection of the basic formula for hand cream, in Chapter 4, a factorial experiment was designed to show the relationships between the input variables (ingredients) and output variables (sensory attributes).

From the basic formulation, five ingredients including mineral oil, rice bran oil, glyceryl monostearate, glycerine, and stearic acid were selected to be input variables and the other two ingredients, triethanolamine and water were fixed variables. In panel training, it was found that the product from the basic formulation was sticky according to the panelists, so isopropyl myristate was added into the formula to get rid of this unpleasant characteristic. Hence, six input variables were studied. A fractional factorial design was used in order to reduce the number of experimental runs to a manageable number.

7.2 LITERATURE REVIEW

A quarter 2^6 factorial design was used in this study to show the main effects of the important input variables on the output variables.

7.2.1 Quarter-Replicate of a 2^6 Experiment

To obtain a quarter-replicate, 2 factorial effects must be used as defining contrasts to divide the 64 combinations into 4 sets of 16. Cochran and Cox (1957) mentioned that in the best design for the 2^6 factorial in a quarter replicate, the defining contrasts, and all aliases of the main effects and of two factor interactions must be interactions of high order that can be assumed negligible. They also stated that the best procedure is to select as defining contrasts 2 four-factor interactions like ABCE and ABDF that have two letters in common. Their generalized interaction, the third defining contrast, is another four-interaction CDEF.

With this design it is clear that the alias of any main effect is an interaction among at least three factors. Some of the aliases of two-factor interactions, however, are themselves two-factor interactions.

The plan for this quarter-replicate can be written down by using ABCE to divide the 64 combinations into halves, and then using ABDF to divide the chosen half into quarters. If the selected quarter is (ABCE, ABDF) = (0,0), the following 16 treatment combinations are used in the factorial design; 2^{6-2},

abcdef	abdf	cdef	abce	acd	ade	bcd	bde
acf	aef	bcf	bef	ab	ce	df	(1)

7.2.2 Regression Analysis

In order to use efficiently the data obtained from the experiment, the researcher can summarize the results using a mathematical equation. Developing equations is an easy way to show the relationship between input and output variables. These models can be used to predict response values for different factor levels after data have been collected and analyzed. In this study, MUTAB computer program (Boag, 1988) was used to develop the empirical equations by conducting regression analysis.

Regression analysis can give the exact relation between sensory perceptions and ingredients. This method is particularly useful in areas where less is known by the developer about the sensory properties and their relationship to ingredients. It attempts to fit an equation to the data, relating panelist rating to ingredient levels. The experimenter can measure the degree to which the linear equations fit the data by three separate measures: the multiple R^2, the F ratio, and the t statistic (Moskowitz, 1987).

The adequacy of fit of each of the models to the observed data is assessed using the F ratio which is the ratio between the lack of fit mean square and the experimental error mean square. Therefore,

$$F(n_1,n_2) = \frac{\text{MS lof}}{\text{MS pure}}$$

where, MS lof = mean sum of squares due to lack of fit.

MS pure = mean sum of squares due to pure error.

n_1, n_2 = degree of freedom for lack of fit and pure error respectively.

If the ratio is not significant, it is concluded that the errors about the fitted model (lack of fit) are the same order of magnitude as those accounted for by error of observation (experimental error) and the model is an adequate representation of the data.

The t statistic is calculated for each of the independent variables (O'Mahony, 1986) as:

$$t = r\sqrt{(N-2)/(1-r^2)}$$

where, N = number of independent variables in the model

r = correlation coefficient

The value of t is compared with the t-table value (two tailed test) at df = N-2. Independent variables whose coefficients' t-values are not significant at $p \leq 0.05$ are omitted from the model and only those with significant values of t contribute to the final model.

In the experimental design and analysis of results, the actual values of the variables are coded +1 for high level and -1 for low level, therefore, the equations derived form the regression analysis also utilises these coded values. To convert them back to the original variables, decoding needs to be carried out. This is done by substituting into:

$$\text{Coded variable} = \frac{\text{Actual variable} - (\text{high} + \text{low})/2}{(\text{high}-\text{low})/2}$$

7.3 EXPERIMENTAL PLANNING FOR FORMULATION DEVELOPMENT

The experimental planning stages required for the systematic formulation development of the hand cream were:

* Establish the basic formulation.
* Plan and conduct a factorial experiment.
* Determine the mean scores for sensory attributes of the

formulations by trained panel testing and physical attributes by objective measurements.

* Analyze the mean scores from the factorial experiment to obtain linear empirical equations showing the relationships between the input and output variables. These linear equations were used in linear programming for product optimization.

7.4 ESTABLISHING THE BASIC FORMULATION

From the basic formula obtained in Chapter 4 and the isopropyl myristate added later, the initial hand cream base formulation was derived as shown in Table 7.1.

TABLE 7.1 Initial Hand Cream Base Formulation

Ingredients	% Total Mix
Mineral oil, (Medium viscosity)	8.0
Rice bran oil	5.0
Glyceryl monostearate (self-emulsifying)	10.0
Glycerine	5.0
Stearic acid, triple press	2.5
Isopropyl myristate	3.0
Triethanolamine	1.5
Water	q.s. to a total of 100

7.5 FACTORIAL EXPERIMENT

A 2^{6-2} fractional factorial design was used to show the main effects of the six significant independent variables at two levels.

A full factorial design with six variables at two levels giving 64 experimental runs, would have been preferable;
however, because of the number of independent variables and the time involved to execute all of the 64 runs it was decided that it would be more convenient to reduce the number of runs by conducting a quarter or fractional factorial design 2^{6-2}, giving 16 experimental runs (2x2x2x2). The assumption from Cochran and Cox (1957), Box et al. (1978), Chow et al. (1983), that interactions involving three or more factors can be considered negligible was applied.

The independent variables and levels were determined from the preliminary experiment; they are outlined in Table 7.2.

TABLE 7.2 Independent variables for study in fractional factorial design.

Independent variable	Low level (%)	High level (%)
A - Rice bran oil	5.0	10.0
B - Mineral oil	1.0	8.0
C - Glyceryl monostearate	3.0	10.0
D - Glycerin	3.0	5.0
E - Stearic acid	1.0	3.0
F - Isopropyl myristate	3.0	8.0

The remaining ingredients and the process variables were set at the levels shown below:

* Triethanolamine (85%) 1.5%
* Water - to balance formulation to 100%
* Mixing temperature 70 - 75 °c
* Mixing time 2 minutes

7.5.1 Fractional Factorial Design

The lay out of the fractional factorial design used for this project is outlined in Table 7.3. In the design there were six main effects and 15 two factor-interactions. The main effects were aliased with the three-factor interactions. For further details on the construction of fractional factorial designs refer to Cochran and Cox (1957).

TABLE 7.3 Fractional Factorial Design for Six Variables

Treatment Codes	Independent Variable					
	A	B	C	D	E	F
1	-	-	-	-	-	-
ab	+	+	-	-	-	-
acd	+	-	+	+	-	-
bcd	-	+	+	+	-	-
ce	-	-	+	-	+	-
abce	+	+	+	-	+	-
ade	+	-	-	+	+	-
bde	-	+	-	+	+	-
acf	+	-	+	-	-	+
bcf	-	+	+	-	-	+
df	-	-	-	+	-	+
abdf	+	+	-	+	-	+
aef	+	-	-	-	+	+
bef	-	+	-	-	+	+
cdef	-	-	+	+	+	+
abcdef	+	+	+	+	+	+

7.5.2 Hand Cream Preparation and Testing

Hand cream processing described in Chapter 4 was used to make 16 hand cream samples as mentioned in the experimental design. Then 15 g of hand cream from each treatment was placed in a 20 ml plastic sample bottle and kept at room temperature before testing. These samples were aged at least 48 hours before being evaluated, to allow any crystal structure or separation of emulsion which was going to develop to do so.

A trained panel of 12 panelists was used for sensory evaluation. The panelists evaluated the hand cream samples as they did in the panel training (Chapter 6). Samples were randomly presented to the panelists. Each panelist attended 6 sessions with three samples in each session. Fourteen samples were tested 12 times, and two samples (BDE, BEF) 24 times. Mean scores and ideal ratio scores were calculated.

Physical attribute measurements with, Ferranti-Shirley viscometer and Bostwick consistometer were also used to test the samples, using the methods described in Chapter 4.

Multiple regression with the coded data was used to identify the sensory attribute/ingredient relationships, physical attribute/ingredient relationships. Sensory attributes and physical attributes correlation were also determined. The linear empirical equations were decoded as described in Section 7.2; to give the final relationships for use in the linear programming.

7.6 ANALYSIS OF THE SENSORY TESTING AND PHYSICAL TESTING RESULTS FROM THE FRACTIONAL FACTORIAL EXPERIMENT

Table 7.4 summarises the results from the fractional factorial experiment for the hand cream formulation. The mean of responses obtained from the sensory evaluation and the physical tests are tabulated in Table 7.4 together with the standard deviation.

TABLE 7.4 Mean Scores of Sensory and Physical Testing from the Fractional Factorial Experiment

Treatment	Attributes									
	Consistency	Spreadability	Absorbability	Oiliness	Shine	Stickiness	Moistness	Softness	Viscosity[a]	Consistency[b]
1	2.9(1.1)[c]	3.3(1.2)	6.7(2.8)	5.9(3.2)	6.1(3.2)	3.4(1.2)	9.2(2.3)	8.1(1.5)	1.03	9.6
ab[d]	3.8(1.6)	3.7(1.0)	8.5(2.1)	7.5(2.3)	6.7(2.0)	6.6(2.3)	8.4(2.0)	8.5(1.5)	1.36	6.8
acd	6.5(2.2)	5.6(2.1)	7.3(2.0)	5.2(2.5)	4.4(2.7)	7.4(2.3)	7.9(2.3)	8.4(1.8)	4.40	2.3
bcd	6.5(2.7)	6.3(2.9)	8.5(2.1)	4.3(2.0)	3.8(1.9)	5.7(2.2)	7.6(2.1)	8.1(2.3)	3.40	0.9
ce	6.8(1.8)	6.1(2.0)	8.2(2.6)	4.0(1.0)	4.0(1.4)	6.8(2.1)	7.6(2.5)	7.7(1.5)	8.70	2.3
abce	9.4(2.1)	6.8(2.0)	8.6(2.8)	5.9(1.8)	5.2(1.9)	8.6(1.6)	7.8(1.4)	8.0(1.6)	9.90	0.0
ade	4.9(3.7)	4.2(3.2)	6.8(2.6)	8.0(1.6)	7.6(2.7)	5.9(1.7)	8.1(2.5)	9.4(1.6)	0.52	7.9
bde	5.8(2.2)	5.0(1.6)	7.8(2.7)	6.9(2.1)	6.5(2.6)	5.5(1.8)	7.0(1.7)	8.1(1.3)	5.69	6.6
acf	9.0(2.3)	7.7(2.4)	7.5(2.7)	5.1(1.8)	4.8(2.2)	7.0(2.6)	6.8(1.6)	7.4(1.7)	10.91	0.0
bcf	10.1(2.0)	8.2(2.2)	7.8(2.5)	7.4(2.6)	6.2(2.7)	8.1(3.1)	7.9(1.8)	8.5(1.9)	9.76	0.0
df	4.5(2.0)	3.8(1.6)	8.4(2.2)	7.0(3.8)	6.5(3.3)	4.3(2.0)	8.8(1.7)	9.1(1.8)	2.76	5.4
abdf	4.8(2.3)	4.8(2.2)	7.6(1.9)	9.0(2.1)	9.3(1.6)	7.0(3.1)	9.1(1.7)	8.7(1.4)	3.33	3.5
aef	5.7(1.7)	4.3(1.6)	9.1(1.7)	7.9(2.0)	7.0(3.8)	5.0(1.3)	8.7(2.0)	8.9(1.9)	1.58	3.0
bef	7.3(2.2)	5.0(1.8)	9.1(2.3)	8.1(1.4)	8.0(2.1)	7.1(2.5)	9.2(1.9)	8.9(2.1)	6.50	3.1
cdef	9.6(1.9)	7.6(1.6)	9.2(2.3)	5.0(1.9)	4.0(1.6)	7.0(2.7)	7.5(1.9)	8.6(1.6)	12.24	1.0
abcdef	11.4(2.4)	8.9(3.0)	6.8(2.4)	7.2(2.1)	7.4(2.1)	8.5(2.6)	8.3(8.3)	8.6(1.6)	13.73	0.0

NOTE:
a - viscosity (poise) measured by Ferranti-Shirley viscometer
b - consistency (cm) measured by Bostwick viscometer
c - standard deviation
d - Factor a - Rice bran oil; Factor b - Mineral oil; Factor c - Glyceryl monostearate; Factor d - Glycerine; Factor e - Stearic acid; Factor f - Isopropyl myristate

The mean of the variable response results from the sensory assessment panel (trained panel), and the results from the physical tests were entered into a regression analysis program - MUTAB. Mathematical models or empirical regression equations were developed for each response; the independent variables were regressed against the output variables.

7.6.1 Relationships between Sensory Attributes and Hand Cream Ingredients

From the sensory evaluation results, the mean scores of each sensory attribute were regressed against levels of all ingredients in every run. From the experimental design used in this study only the main effects of the independent variables could be detected. Hence, sensory attributes were regressed against main effects only. The main effects which exhibited a t-ratio significant at $p \leq 0.05$ were included in the equations, otherwise they were ignored. The decoded regression equations developed for each of the response variables using the MUTAB program are listed in Table 7.5.

From Table 7.5, it can be seen that glyceryl monostearate had great effects on hand cream sensory attributes as it's effect was significant in every empirical equation, except absorbability. Consistency, spreadability, oiliness, shine and stickiness had significant linear relationships with the hand cream ingredients. Absorbability did not have a linear relationship with the main effects, there might be some interaction between ingredients which affected the absorbability of hand cream. This interaction, if there was any, was assumed to be interaction between stearic acid and isopropyl myristate. This interaction could be tested by using 2^2 factorial experiment with centre points; however, this was not included in this study. As moisture and softness of the samples in each run were very similar, it was unlikely that linear equations, showing significant relationships between these attributes and ingredients, could be obtained.

TABLE 7.5 Regression Equations Showing Relationships between Sensory Attribute and Input Variables.

Regression Equation				R^2 x100(%)	t-Ratio
Consistency	= -1.137	+	.164(MO)	94.14	3.30**
		+	.529(GMS)		10.62***
		+	.800(STR)		4.59***
		+	.395(IPM)		5.67***
Spreadability	= 1.256	+	.109(MO)	90.87	2.60*
		+	.413(GMS)		9.85***
		+	.232(IPM)		3.96**
Oiliness	= 5.159	+	.180(RBO)	86.47	2.81*
		+	.146(MO)		3.20**
		-	.289(GMS)		-6.32***
		+	.225(IPM)		3.51**
Shine	= 4.882	+	.182(RBO)	85.17	2.52*
		+	.155(MO)		3.01*
		-	.320(GMS)		-6.19***
		+	.222(IPM)		3.08*
Stickiness	= 2.488	+	.202(RBO)	74.19	2.45*
		+	.184(MO)		3.12**
		+	.255(GMS)		4.33***
Moistness	= 8.944	-	.127(GMS)	37.85	-2.92*
Softness	= 8.948	-	.079(GMS)	29.68	-2.43*
Absorbability[a]	= 8.478	-	.088(RBO)	26.64	-0.95[ns]
		+	.027(MO)		0.41[ns]
		-	.002(GMS)		-0.03[ns]
		-	.194(GLY)		-0.84[ns]
		+	.206(STR)		0.89[ns]
		+	.078(IPM)		0.84[ns]

NOTE:
- a - No variables met the significance level for entry, regression was done with all variables forced.
- ns - not significant at $p \leq 0.05$
- * - significant at $0.05 \geq p \geq 0.01$
- ** - significant at $0.01 \geq p \geq 0.001$
- *** - significant at $p \leq 0.001$

Only equations which exhibited R^2 value equal or more than 70% were used in the linear programming model for hand cream optimization. The R^2 value of absorbability, moistness and softness were very low ($R^2 < 70\%$) so the linear relations of these attributes and ingredients were disregarded.

7.6.2 Relationships between Physical Attribute Values and Ingredient Levels

Viscosity and consistency were regressed against ingredient levels in order to find out which ingredients affected the physical properties of the product and to what degree.

TABLE 7.6 Regression Equations Showing Relationships between Physical Attributes and Input Variables.

	Regression Equation	R^2 x100(%)	t-Ratio
Viscosity	= -6.134 + .898(GMS)	81.26	5.98***
	+ 1.369(STR)		2.61*
	+ .645(IPM)		3.07**
Consistency	= 11.505 - .189(MO)	89.59	-2.36*
	- .703(GMS)		-8.78***
	- .510(IPM)		-4.54***

NOTE: * - significant at $0.05 \geq p \geq 0.01$
** - significant at $0.01 \geq p \geq 0.001$
*** - significant at $p \leq 0.001$

It can be seen from Table 7.6 that glyceryl monostearate, stearic acid and isopropyl myristate contributed to the viscosity of the hand cream. Mineral oil, glyceryl monostearate and isopropyl myristate contributed to the consistency of the hand cream.

7.6.3 Correlation between Sensory Attribute Mean Scores and Physical Attribute Values

The correlation coefficients between the sensory attribute mean scores and the physical attribute values were determined. The correlation coefficients and their significance levels are shown in Table 7.7.

Table 7.7 Correlation Coefficients between Sensory Attribute Mean Scores and Physical Attribute Values

Sensory Attribute	Physical Attribute	
	Viscosity	Consistency
Consistency	0.93***	-0.86***
Spreadability	0.92***	-0.87***
Stickiness	0.71**	-0.74**
Moistness	-0.49	0.41
Softness	-0.42	0.33
Oiliness	-0.34	0.33
Shine	-0.32	0.37
Absorbability	0.08	-0.30

NOTE: * - significant at $0.05 \geq p \geq 0.01$
** - significant at $0.01 \geq p \geq 0.001$
*** - significant at $p \leq 0.001$

From the correlation coefficients in Table 7.7, it can be seen that some sensory attributes correlated with the physical attributes. Consistency and spreadability showed very highly significant correlation ($p < 0.001$) with viscosity and consistency. Stickiness showed highly significant correlation ($p < 0.01$) with the two physical attributes. The other sensory attributes were not significantly correlated with either viscosity or consistency.

7.7 DISCUSSION AND CONCLUSION

From the fractional factorial design used in this hand cream experiment, although not all the treatment combinations were tested as in a 2^6 factorial experiment, significant empirical equations showing the relationships between sensory attributes and main effects were obtained. The experiment resulted in 5 significant linear attribute/ingredient relationships. These described the consistency, spreadability, oiliness, shine and stickiness as functions of the ingredients. Therefore these relationships, as shown below, were used straight away to generate the constraints for the linear programming model to find the optimal hand cream product.

$$\text{Consistency} = -1.137 + .164(MO) + .529(GMS) + .800(IPM)$$
$$\text{Spreadability} = 1.256 + .109(MO) + .232(IPM)$$
$$\text{Oiliness} = 5.159 + .180(RBO) + .146(MO) - .289(GMS) + .225(IPM)$$
$$\text{Shine} = 4.882 + .182(RBO) + .155(MO) - .320(GMS) + .222(IPM)$$
$$\text{Stickiness} = 2.488 + .202(RBO) + .184(MO) + .255(GMS)$$

Moistness, softness and absorbability did not have significant linear relationships with ingredients.

As some product sensory attributes had linear relationships with physical attributes so it was possible to predict these sensory attributes during product development by using the physical measures. The physical attribute/ingredient relationships can be used in the linear programming model to obtain the optimum product.

Hand cream optimization using sensory attribute/ingredient relationships and ideal product attributes' levels as constraints in linear programming is described in Chapter 8.

CHAPTER 8

OPTIMIZATION OF THE FORMULATION

The aim of this formulation optimization was to obtain a hand cream product which was highly acceptable to the consumer at low cost and could compete with the products already in the market.

The objectives were:

* To produce a hand cream using rice bran oil to be a substitute for mineral oil.

* To develop sensory constraints for a linear programming model in hand cream formulation using sensory/ingredient linear relationships obtained from the former factorial experiment together with the consumers' ideal product profile.

* To optimise the sensory characteristics of the product, with the minimum costs.

* To produce a hand cream that can compete with the ones that are available in the marketplace.

8.1 OPTIMIZATION PLANNING

In the optimization process, linear programming was used to identify the optimum formulation for the hand cream. The product from this formulation was made and tested by the trained panel then tested by a consumer panel to measure the consumers' acceptability. The optimization plan was:

* Develop the linear programming model from the empirical equations of sensory attribute/ingredient relationships and consumers' ideal product profile.

* Make the product prototype from the optimum solution obtained from solving the linear programming problem.

* Determine the sensory attributes of the formulation by conducting trained panel testing.

* If the formulation is acceptable, determine the acceptability of the formulation by conducting a consumer product testing.

* Finalise the formulation.

8.2 DEVELOPING THE LINEAR PROGRAMMING MODEL

To solve a linear programming problem, three major components have to be set. They are the objective function, decision variables, and constraints.

8.2.1 Objective Function

The objective function of this optimization was to minimize the cost of the optimum hand cream. The costs of the ingredients used in this study are shown in Table 8.1.

Table 8.1 Costs of the Ingredients Used in Hand Cream Formulation[a]

Ingredients	Cost $/kg
Rice bran oil	9.00
Mineral oil	4.35
Glyceryl monostearate (self-emulsifying)	11.50
Glycerine	5.50
Stearic acid	3.15
Isopropyl myristate	9.00
Triethanolamine	5.00

NOTE: [a] - Provided by Bronson and Jacobs (N.Z.) Limited, Auckland.

The objective was to minimize the cost of a 100-kg batch of the hand cream product. Hence, the objective function was:

minimize

$$Z = 9.00(RBO) + 4.35(MO) + 11.50(GMS) + 5.5(GLY) + 3.15(STR) + 9.00(IPM) + 5.00(TEA)$$

where the value of ingredients are the weights (in kg) of the ingredients and the coefficients were the per-unit costs. Water was assumed to have no cost.

8.2.2 Decision Variables

The decision variables for the hand cream formulation were the six ingredients which are listed in Table 8.2.

Table 8.2 Decision Variables in Hand Cream Formulation

Ingredients	Variables
Rice bran oil	x_1
Mineral oil	x_2
Glyceryl monostearate (self-emulsifying)	x_3
Glycerine	x_4
Stearic acid	x_5
Isopropyl myristate	x_6
Triethanolamine	x_7
Water	x_8

8.2.3 Constraints

Constraint (1) was the batch size constraint. The batch size of 100kg was chosen so that the final values of the decision variables could be interpreted as either kilograms or percent of total.

The sensory constraints were developed from the empirical equations obtained from the regression analysis in section 7.8. The product ideal attribute levels obtained from consumer testing in Chapter 5, were used to generate the upper and lower bounds of the sensory constraints, constraints (2) - (11). Upper and lower bounds were calculated, by adding 1 and subtracting 1 from the ideal attribute levels. Because each sensory attribute/ingredient relationships contained a constant term, a dummy variable, was defined to have the constant's value for every sensory variable, was defined to have the constant's value for every sensory constraint. x_9, x_{10}, x_{11}, x_{12} and x_{13}, in constraints (22) - (31), were dummy variables for consistency, spreadability, oiliness, shine and stickiness constraints respectively.

Ingredient constraints, constraints (12) to (21), were derived from the basic hand cream formulation. Lower limit of rice bran oil constraint was set at 5% which was the amount of rice bran oil in the basic formulation and upper limit was set at 20%. Upper limit of mineral oil constraint was set at 10%, less than upper limit of rice bran oil in order that the formulation contained more rice bran oil which was the aim of the project. The lower limit for mineral oil was 0%. The upper bound of water was set at 85% so that, there would not be too much water in the optimum solution which could cause the emulsion breakdown. Constraint (24), triethanolamine constraint, was the invariant constraint and was set at 1.5%. Other ingredients were assigned upper and lower limits based on the initial formulation. These limits were set as wide as possible in order to get a feasible solution - glyceryl monostearate, 3-5%; glycerine 3-8%, isopropyl myristate 3-10%. The constraints are shown in Figure 8.1.

TOTAL	(RBO+..+WATER) = 100	(1)
<u>SENSORY CONSTRAINTS</u>		
CONSISTENCY	.164*MO+.529*GMS+.8*STR+.395*IPM-X.9 ≥ 4.47	(2)
CONSISTENCY	.164*MO+.529*GMS+.8*STR+.395*IPM-X.9 ≤ 6.47	(3)
SPREADABILITY	.109*MO+.413*GMS+.232*IPM+X.10 ≥ 3.3	(4)
SPREADABILITY	.109*MO+.413*GMS+.232*IPM+X.10 ≤ 5.3	(5)
OILINESS	.18*RBO+.146*MO-.289*GMS+.225*IPM+X.11 ≥ 2.39	(6)
OILINESS	.18*RBO+.146*MO-.289*GMS+.225*IPM+X.11 ≤ 4.39	(7)
SHINE	.182*RBO+.155*MO-.32*GMS+.222*IPM+X.12 ≥ 3.8	(8)
SHINE	.182*RBO+.155*MO-.32*GMS+.222*IPM+X.12 ≤ 5.8	(9)
STICKINESS	.202*RBO+.184*MO+.255*GMS+X.13 ≥ 0	(10)
STICKINESS	.202*RBO+.184*MO+.255*GMS+X.13 ≤ 5	(11)
RICE BRAN OIL	RBO ≥ 5	(12)
RICE BRAN OIL	RBO ≤ 20	(13)
MINERAL OIL	MO ≥ 0	(14)
MINERAL OIL	MO ≤ 10	(15)
GLYCERYL MONOSTEARATE	GMS ≥ 3	(16)
GLYCERYL MONOSTEARATE	GMS ≤ 15	(17)
GLYCERINE	GLYCERINE ≥ 3	(18)
GLYCERINE	GLYCERINE ≤ 8	(19)
STEARIC ACID	STEARIC ≥ 3	(20)
STEARIC ACID	STEARIC ≤ 8	(21)
ISOPROPYL MYRISTATE	IPM ≥ 3	(22)
ISOPROPYL MYRISTATE	IPM ≤ 10	(23)
TRIETHANOLAMINE	TEA = 1.5	(24)
WATER	WATER ≥ 0	(25)
WATER	WATER ≤ 85	(26)
x9	X.9 = 1.137	(27)
x10	X.10 = 1.256	(28)
x11	X.11 = 5.159	(29)
x12	X.12 = 4.882	(30)
x13	X.13 = 2.488	(31)

Figure 8.1 Constraints for Hand Cream Linear Programming Model

Table 8.3 Constraints for Linear Programming Model

	Ingredient													
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	RHS
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000						= 100.0
Consistency		.164	.529		.800	.395			-1.000					≥ 5.607
Consistency		.164	.529		.800	.395			-1.000					≤ 7.607
Spreadability		.109	.413			.232				1.000				≥ 2.044
Spreadability		.109	.413			.232				1.000				≤ 4.044
Oiliness	.180	.146	-.289			.225					1.000			≤ 2.769
Oiliness	.180	.146	-.289			.225					1.000			≥ 0.000
Shine	1.820	.155	-.320			.222						1.000		≤ 1.082
Shine	1.820	.155	-.320			.222						1.000		≤ 8.000
Stickiness	.202	.184	.255										1.000	≤ 2.488
Stickiness	.202	.184	.255										1.000	≤ 2.512
x_1	1.000													≥ 5.00
x_1	1.000													≤ 20.00
x_2		1.000												≥ 0.00
x_2		1.000												≤ 10.00
x_3			1.000											≥ 3.00
x_3			1.000											≤ 15.00
x_4				1.000										≥ 3.00
x_4				1.000										≤ 8.00
x_5					1.000									≥ 3.00
x_5					1.000									≤ 8.00
x_6						1.000								≥ 3.00
x_6						1.000								≤ 10.00
x_7							1.000							= 1.50
x_7								1.000						≥ 0.00
x_8								1.000						≤ 85.00
x_9									1.000					= 1.137
x_{10}										1.000				= 1.256
x_{11}											1.000			= 5.159
x_{12}												1.000		= 4.882
x_{13}													1.000	= 2.488

8.2.4 Initial Investigation of the Model

In first running the model on the computer using LP88, no feasible solution was obtained. The upper limit for oiliness was identified as the constraint causing non-feasibility. The upper limit for oiliness was increased from 4.39 to 5.1 and then a feasible solution was obtained. The final linear programming model used to obtain the optimum formulation is shown in Table 8.3.

8.3 LINEAR PROGRAMMING AND OPTIMUM FORMULATION

LP88 computer program was used to solve this hand cream problem. Objective function, decision variables and constraints described above were entered into the computer, and the optimum solution obtained is presented in Table 8.4.

Table 8.4 Optimum Formulation Obtained from Linear Programming

Ingredients	%
Rice Bran oil	5.00
Mineral oil	0.00
Glyceryl monostearate (Self-emulsifying)	5.65
Glycerine	3.00
Stearic acid	3.00
Isopropyl myristate	3.00
Triethanolamine (85%)	1.50
Water	78.85
Total	100.00
Cost ($/100kg)	170.47

The predicted scores for the attributes in the model for the hand cream made from this formulation are shown in Table 8.5.

8.4 PREPARATION OF OPTIMUM HAND CREAM

A hand cream formulation was made from the optimum formulation using the processing method described in Chapter 4. Samples which were used for panel testing were placed into 20 ml plastic sample bottles and kept at room temperature for 48 hours before testing.

8.5 OPTIMUM PRODUCT TESTING

The hand cream made from the optimum formulation was tested by physical testing and sensory testing methods.

The sensory evaluation was carried out by the trained panel consisting of 12 panelists. The quantitative sensory profile method was again applied for the sensory evaluation. The questionnaire used was similar to that displayed in Figure 6.5., Chapter 6.

The trained panel sensory scores for each of the attributes evaluated were averaged. The mean deviation from the consumers' ideal was calculated, expressed as the ratio of the average attribute score to the average ideal score for the attribute obtained from consumer testing in Chapter 5. The results were compared with the results of product coded 803, the best competitive product, which was obtained from panel training in Chapter 6 as shown in Table 8.5.

Table 8.5 Mean Scores and Ideal Ratio Scores of Optimum Product and Commercial Product Obtained from Trained Panel Sensory Testing

Attribute	Optimum product			803	
	Predicted score	Mean panel score	Ideal ratio	Mean panel score	Ideal ratio
Sensory attribute					
Consistency	5.4	4.3	0.79	6.5	1.19
Spreadability	4.3	3.6	0.84	5.1	1.19
Absorbability	-	8.9	0.74	8.3	0.69
Oiliness	5.1	4.7	1.39	4.8	1.42
Shine	4.6	3.3	0.69	4.1	0.85
Stickiness	4.9	4.4	-	6.7	-
Moistness	-	8.6	0.82	7.3	0.69
Softness	-	9.1	0.77	7.5	0.64
Physical attribute					
Viscosity		4.21		5.65	
Consistency		2.9		1.8	

From Table 8.5 the actual sensory attribute values of the optimum product were not different from the predicted attribute values. Ideal ratio scores of both optimum product and commercial product showed that the product obtained from the optimum solution was closer to the ideal product in terms of spreadability, absorbability, oiliness, moistness, and softness than the commercial product. The formulation could be improved in order to obtain a product which is closer to the ideal product by adjusting the constraints in the linear programming until a formulation with the desired properties is obtained.

8.6 CONSUMER TESTING

Although the hand cream was not exactly ideal, only oiliness and shine were more than 0.3 away from the ideal and therefore it was decided to test this product with the consumer panel to ascertain if the product would be accepted by the consumer and could compete with the products already in the market.

The consumer panel consisted of 19 women who were staff and students at the Technology Faculty, Massey University, all of them were hand cream users. These consumers were asked to come to the sensory testing room and test the samples as described in Chapter 5.

The consumers were asked to test the sample from the optimum formulation with two commercial products, coded 803 and 451, as used in consumer testing in Chapter 5 and panel training in Chapter 6. The product coded 803 was chosen because it was assigned the highest overall liking score in the consumer testing. Product coded 451 was chosen because its 'after feel' attributes' scores were nearest to those of the consumers' ideal product. The product from the optimum formulation was tested along with the commercial products in order that the sensory attributes of the sample could be compared with those of products in the marketplace.

The questionnaire used in this test is shown in Figure 8.2. Consumers were also asked to rate their overall liking and purchase intent on the samples. These were used to indicate their acceptability on the product and also show whether the purchase intent related with overall liking or not.

The means of consumer panelists' scores of every sample for each of the attributes were determined. The ideal ratio score of each panelist was calculated by dividing the panelist's sample score by panelist's ideal score

and the mean ideal ratio scores determined. The results are shown in Table

HAND CREAM SENSORY TESTING

NAME ____________________ DATE ______________

I am Hathairat Uaphithak, a Master degree student in Product Development sub-department. I am developing a new hand cream product. Please read the instruction before testing the samples.

Instructions: You will 3 samples of hand creams. Please evaluate these creams according to the given order.

Take an appropriate amount of hand cream from the container with the index finger of one hand. While lifting the finger out of the container, evaluate the consistency of the sample. Spread it with three fingers over the back of the other hand, then test another sample on the other hand. Between each session wash your hands with the given detergent and dry them properly, then do another session. Rate your reaction to each product and your ideal product on the scales in the questionnaire by placing a mark across the line at the point which represents what you perceive.

Example:

Thickness

254 I 345 259

low ———————— medium ———————— high

The process of testing will be divided into 3 stages:

1. Pick up: product removed from container.

2. Rubout: spread of product over and into skin with fingertips using gentle circular motion for a period of time, depending on the product.

3. After-feel: evaluation of skin surface with fingertips, and visually after product application.

NAME ____________________ DATE ______________

PRODUCT SAMPLE _____ _____ _____

PRODUCT ATTRIBUTE

1. PICK UP

Consistency

light ———————— medium ———————— heavy

2. RUB OUT

Spreadability

slip easily ———————— moderately easy ———————— drags

Absorbability

slow ———————— moderate ———————— fast

3. AFTER FEEL

Oiliness

not oily ———————— medium ———————— very oily

Shine

low ———————— medium ———————— high

Stickiness

not sticky ———————— moderately sticky ———————— very sticky

Moistness

not moist ———————— medium ———————— very moist

Softness

not soft ———————— medium ———————— very soft

4. Overall Liking

low ———————— medium ———————— high

5. Purchase Intent

low ———————— medium ———————— high

Figure 8.2 Questionnaire for Consumer Testing and the mean ideal ratio scores determined. The results are shown in Table 8.6.

Table 8.6 Consumer Panelists' Mean Scores and Ideal Ratio Scores of Optimum Product and Two Commercial Products.

Attribute	Optimum product		803		451	
	Mean score	Ratio score	Mean score	Ratio score	Mean score	Ratio score
Consistency	5.0	0.9	5.3	1.0	9.5	2.0
Spreadability	3.5	1.1	3.2	1.0	6.6	2.0
Absorbability	9.3	0.9	6.8	0.7	6.5	0.6
Oiliness	5.5	1.6	6.1	2.0	8.8	2.9
Shine	4.5	1.0	5.7	1.3	9.6	2.1
Stickiness	4.5	1.6	5.8	2.3	8.0	3.4
Moistness	9.3	0.9	9.1	0.9	8.5	0.8
Softness	9.2	0.8	8.9	0.8	8.3	0.8
Overall liking	10.8	-	9.3	-	5.9	-
Purchase intent	10.5	-	8.4	-	5.2	-

The results in Table 8.6 shown that the product obtained from the optimum formulation contained sensory attributes whose levels were near those of the consumers' ideal product. Consistency, spreadability, absorbability, shine, moistness, softness were within 0.2 of the ideal ratio of one; oiliness and stickiness were 0.6 higher than 1, but other products had even higher ratio scores. Also the overall liking and purchase intent for the optimum product obtained higher scores than those of the commercial products.

It can be seen that the optimum product had an absorbability level, the most important attribute identified in Chapter 5, nearest to the ideal product (ideal ratio score 0.9) when compared with the other two commercial products 803 and 451 which received the ideal ratio scores for absorbability 0.7 and 0.6 respectively.

Comparison between ideal scores obtained from the first consumer testing in Chapter 5 and those from this consumer testing are shown in Table 8.7. The ideal attribute levels from both consumer testings were similar.

Table 8.7 Comparison between Ideal Ratio Scores Obtained from Two Consumer Testing

Attribute	First Consumer Testing's Mean Ideal Scores	Second Consumer Testing's Mean Ideal Scores
Consistency	5.5	5.6
Spreadability	4.3	3.6
Absorbability	12.0	10.7
Oiliness	3.4	3.8
Shine	4.8	5.5
Moistness	10.5	10.7
Softness	11.8	11.0

8.7 DISCUSSION AND CONCLUSION

The optimum product obtained from the linear programming model had potential to be accepted by the consumers. However this product has to be tested in home-use testing before launching to the market to ascertain that it could compete with the product already in the market. Storage tests would have to be done to determine if the hand cream properties changes on storage.

The linear programming model using sensory/ingredient linear relationships as constraints of the model can be used to optimize the product in product development in order to obtain a highly acceptable product at a low cost. Measuring the importance of product attributes at the beginning of the optimization process allows the experimenter to develop the product which contains sensory attributes at the levels which are acceptable. Product optimization using linear programming to optimize sensory attributes is an excellent method to obtain the optimum product if the sensory/ingredient relationships are linear and the interactions between ingredients are negligible.

The system used in this study is easy to use in any product categories in which the sensory/ingredient relationships are linear. Since the consumers' ideal product profile is used so it is possible to obtain the product which possesses the attribute levels near those of the ideal product. By using linear programming, if ingredients costs change, their effects on the sensory attribute of the optimum solution can be easily assessed.

CHAPTER 9

DISCUSSION AND CONCLUSION

9.1 INTRODUCTION

The work described in this thesis was aimed at optimizing the sensory attributes of hand cream products, using consumers' ideal product sensory profile in conjunction with linear programming. Previous studies on linear programming for product optimization did not appear to use consumers' ideal product profile in the model although sensory attribute/ingredient relationship were used to generate the constraints (Beausire et al., 1988).

The hand cream product developed in this study was considered to be acceptable by the consumers and was rated higher in terms of overall liking and purchase intent than the commercial products used in this study.

9.2 THE USE OF CONSUMER TESTING AT THE FIRST STAGES OF PRODUCT OPTIMIZATION

Studying weaknesses and strengths of the existing products at the beginning of the product optimization is an important step since consumers are the best people to tell how they perceive these products. Consumers can also identify whether the product should be improved, in what attributes and possibly by how much. In this study, the weaknesses of the competitors were identified and were used as keys to develop the new product.

The consumer can also identify their ideal product profile when they are testing the competitive product, and this can be used to set the limits for the attributes in the linear programming model.

9.3 USE OF QUANTITATIVE SENSORY PROFILE AND TRAINED PANEL FOR SENSORY EVALUATION

The quantitative sensory profiling and trained panel were used to determine the quantitative values of sensory attributes for the different samples in the experiment which were then regressed with the ingredients of the products.

Trained panel used in this study worked reasonably well in providing the quantitative sensory data and they were also useful in predicting the consumers' perception on the developed product.

9.4 USE OF EXPERIMENTAL DESIGN IN HAND CREAM DEVELOPMENT

In this research, a quarter factorial design was used to study the effects of ingredients on sensory and physical attributes of hand cream. Relationships of sensory attributes and ingredients of the product obtained from experimental designs are very useful in assigning the constraints in the linear programming model as these relationships contain the main effects of the ingredients which affect the sensory attributes of the product. In comparison with the sequential procedure followed by some optimization techniques, this method consider all significant attributes in the sensory equations. Hence, it is very useful for product optimization in which the experimenter is not familiar with the product and cannot predict which ingredients should have significant effects on the product.

The relationships between sensory attributes and ingredients must be linear to be used in linear programming, and this may limit the use of this method of product optimization.

9.5 USE OF CONSUMERS' IDEAL PRODUCT PROFILE, SENSORY ATTRIBUTES AND INGREDIENTS RELATIONSHIPS, IN LINEAR PROGRAMMING MODEL

Consumer product ideal profile has advantage of showing clearly whether the sensory attributes of the product are close to the consumers' ideals and simultaneously showing in what direction the product should be improved in order to be highly accepted by the consumers. Also using ideal attribute level in the sensory constraints for linear programming model is more straight forward than using an acceptability constraint derived from sensory attribute/acceptability relationships. The number of attribute levels is not limited by using sensory attribute constraints as long as these attributes possess linear relationships with the ingredients used in the product. The product can be formulated closer to the ideal by adjusting the upper and lower limits of the sensory constraints, however, the cost of product will certainly increase.

Focusing on the important attributes of the product provides the experimenter with direction in deciding whether the formulation obtained from the linear programming solution is the product that consumers want. Sensory constraints can be adjusted in order to obtain the feasible solution as long as the predicted important attributes' levels of the product are not so far from the ideal attribute level that it will affect consumer acceptance of the product.

This work extended the work have done by Beausire et al. (1988), Kavanagh (1978), Chan and Kavanagh (1988) by adding the sensory attribute/ingredient relationships and consumers' ideal product profile in the constraints for the linear programming model.

9.6 RECOMMENDATION FOR FUTURE WORK

Although the final product was successfully developed and reasonably acceptable, there were some points to be suggest for the future work as follows:

* The colour and fragrance can be added in the product formulation in order to improve the acceptability.

* Since the stability of hand cream is the most important aspects in terms of the product's quality, therefore stability testing of the developed product should be carried out.

* The product was only tested by consumer laboratory test in the final stage of this study. It was believed that home-used test was needed in order to attain some more data and information to justify whether the developed hand cream could be launched and could compete with the existing products.

9.7 CONCLUSION

This study demonstrates the usefulness of consumers' ideal product profile and linear programming in skin care product optimization. This approach not only increase the consumer acceptability but also produce the formulated product at minimum cost.

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APPENDIX 5.1

Brand Names of the samples used in the consumer testing.

No. 907 SHISEIDO Hand Moisture Cream

No. 251 POND's Cream Cocoa Butter

No. 563 POND's Nourishing Cream

No. 451 NIVEA Cream

No. 682 AVON Glycerine Hand Cream

No. 275 ENRICH Beauty Cream

No. 386 CHANTILLY Ultra Rich Hand & Body Cream

No. 738 CYCLAX Treatment Hand Cream

No. 324 WINTERS Sorbolene Cream

No. 803 BOOTS Light Moisturising Cream

APPENDIX 5.2 Thurstone Case V Comparison Results

Table A5.1 Obsered Proportions Preferring Attribute X (Top of table) Attribute Y (Side of table)

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
V1	-	0.45	0.75	0.90	0.85	0.75	0.70	0.55	0.90	0.90
V2	0.55	-	0.80	0.90	0.90	0.90	0.75	0.60	0.90	0.90
V3	0.25	0.20	-	0.85	0.75	0.70	0.55	0.50	0.80	0.80
V4	0.10	0.10	0.15	-	0.30	0.15	0.25	0.25	0.50	0.25
V5	0.15	0.10	0.25	0.70	-	0.20	0.20	0.40	0.60	0.55
V6	0.25	0.10	0.30	0.85	0.80	-	0.40	0.40	0.70	0.55
V7	0.30	0.25	0.45	0.75	0.80	0.60	-	0.30	0.85	0.65
V8	0.45	0.40	0.50	0.75	0.60	0.60	0.70	-	0.85	0.75
V9	0.10	0.10	0.20	0.50	0.40	0.30	0.15	0.15	-	0.25
V10	0.10	0.10	0.20	0.75	0.45	0.45	0.35	0.25	0.75	-

Table A5.2 Z Values Relate to Preference Proportions in Table A5.1

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
V1	-	-0.13	0.67	1.28	1.04	0.67	0.52	0.13	1.28	1.28
V2	0.13	-	0.84	1.28	1.28	1.28	0.67	0.25	1.28	1.28
V3	-0.67	-0.84	-	1.04	0.67	0.52	0.13	0.00	0.84	0.84
V4	-1.28	-1.28	-1.04	-	-0.52	-1.04	-0.67	-0.67	0.00	-0.67
V5	-1.04	-1.28	-0.67	0.52	-	-0.84	-0.84	-0.25	0.25	0.13
V6	-0.67	-1.28	-0.52	1.04	0.84	-	-0.25	-0.25	0.52	0.13
V7	-0.52	-0.67	-0.13	0.67	0.84	0.25	-	-0.52	1.04	0.39
V8	-0.13	-0.25	0.00	0.67	0.25	0.25	0.52	-	1.04	0.67
V9	-1.28	-1.28	-0.84	0.00	-0.25	-0.52	-1.04	-1.04	-	-0.67
V10	-1.28	-1.28	-0.84	0.67	-0.13	-0.13	-0.39	-0.67	0.67	-
TOTAL	-6.75	-8.3	-2.53	7.18	4.03	0.46	-1.34	-3.04	6.93	3.37
MEAN	-0.68	-0.83	-0.25	0.72	0.40	0.05	-0.13	-0.30	0.69	0.34
R*	0.15	0.00	0.58	1.55	1.23	0.88	0.70	0.53	1.52	1.17

NOTE: R* - adjusted mean value

APPENDIX 5.3 Sensory Attribute Scores and Ideal Ratio Scores of Ten Commercial Products Obtained from Consumer Testing

Table A5.3 Profiles of Ten Hand Cream Products Derived from Consumer Testing [a]

Attribute	Ideal [b]		907		251		563		451		682		275		386		738		324		803	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Thickness	6.83	1.55	8.01	2.61	3.92	2.63	7.21	2.88	11.99	1.50	7.63	3.01	5.04	3.12	7.09	2.07	7.27	2.63	8.67	2.03	6.94	2.48
Consistency	5.47	2.16	8.34	2.92	3.97	2.93	6.71	3.41	11.12	2.88	7.91	2.55	4.58	2.93	7.40	2.43	6.32	2.45	8.30	1.97	5.78	2.40
Spreadability	4.30	2.20	7.82	3.27	3.05	1.12	6.05	3.24	9.18	3.39	5.88	2.33	3.29	1.14	6.30	3.09	5.62	2.63	5.63	3.20	4.37	1.94
Absorbability	11.96	1.63	8.55	3.85	6.98	3.84	5.93	2.28	7.79	3.56	8.55	3.60	7.14	2.89	7.05	2.74	8.06	2.81	4.13	2.97	8.59	3.49
Time to work in	2.84	1.69	6.09	3.46	6.72	3.78	7.62	1.97	7.37	3.61	6.00	3.38	6.45	2.81	6.94	3.23	6.95	2.86	9.37	3.39	5.61	2.85
Speed of drying	11.61	2.67	6.97	2.98	7.72	4.05	5.59	2.44	7.34	3.37	7.67	3.11	9.12	2.72	7.19	2.83	8.95	3.03	5.78	2.62	8.69	3.13
Coating	3.39	2.79	7.27	3.62	6.44	3.74	8.57	3.14	9.24	3.35	7.66	3.16	7.15	2.96	8.07	2.32	4.59	2.53	8.07	2.89	5.66	2.93
Skin appearance	4.80	3.28	5.57	2.52	6.27	3.92	8.45	2.73	9.93	2.37	8.05	3.19	5.75	2.57	6.46	3.15	4.47	2.33	4.57	2.99	5.66	2.30
Skin feel	10.53	3.04	9.62	3.00	10.66	2.08	9.10	3.50	10.57	3.17	9.76	3.70	9.87	2.30	8.91	2.86	6.87	3.16	9.70	2.49	8.97	2.63
Skin touch	11.79	1.84	9.17	2.75	8.38	2.48	9.10	2.13	9.17	2.44	8.74	2.21	8.07	2.71	9.69	1.58	8.22	2.67	8.76	1.95	8.78	2.42
Overall liking	-	-	7.03	3.95	8.79	2.66	6.76	2.32	7.29	3.35	7.92	2.39	7.84	3.34	7.54	2.52	7.41	3.07	5.84	3.24	8.99	2.70

Note: [a] - Experiment particulars: number of attributes = 10; number of evaluations/product = 12; scale = 0-15 linear scale

[b] - Consumers' self-designed ideal product, rated on same attributes

APPENDIX 5.3 (continued)

Table A5.4 Ideal Ratio Scores of Ten Hand Cream Products Obtained from Consumer Testing

Attribute	907	251	563	451	682	275	386	738	324	803
Thickness	1.17	0.57	1.06	1.76	1.12	0.74	1.04	1.06	1.27	1.02
Consistency	1.52	0.73	1.23	2.03	1.45	0.84	1.35	1.16	1.52	1.06
Spreadability	1.82	0.71	1.41	2.13	1.37	0.77	1.47	1.31	1.31	1.02
Absorbability	0.71	0.58	0.50	0.65	0.71	0.60	0.59	0.67	0.35	0.72
Time to work in	2.14	2.37	2.68	2.60	2.11	2.27	2.44	2.45	3.30	1.98
Speed of drying	0.60	0.66	0.48	0.63	0.66	0.79	0.62	0.77	0.50	0.75
Coating	2.17	1.90	2.53	2.73	2.26	2.11	2.38	1.35	2.38	1.67
Skin appearance	1.16	1.31	1.76	2.07	1.68	1.20	1.35	0.93	0.95	1.18
Skin feel	0.91	1.01	0.86	1.00	0.93	0.94	0.85	0.65	0.92	0.85
Skin touch	0.78	0.71	0.77	0.78	0.74	0.68	0.82	0.70	0.74	0.74

APPENDIX 6.1 Sensory Attribute Scores Obtained from Panel Testing

Sample	Panelist	consis	spread	absorb	oiliness	shine	moist	soft
803	1	1.7	2.1	13.4	2.2	4.9	11.1	9.8
	2	2.6	2.5	6.5	6.4	3.7	10.0	10.0
	3	3.6	6.0	8.1	6.4	7.0	10.0	8.5
	4	4.0	7.3	8.4	5.5	4.1	8.1	7.6
	5	3.2	3.7	6.5	7.3	10.1	5.5	9.3
	6	3.7	4.2	5.4	8.2	8.1	8.1	8.1
	7	5.0	4.9	4.9	4.8	4.5	5.3	5.5
	8	8.3	7.7	6.5	9.8	5.5	6.3	9.3
	9	2.7	2.7	3.1	12.1	11.1	12.4	12.2
	10	3.2	3.0	6.2	5.5	5.8	8.3	8.3
	11	3.0	2.7	1.6	2.1	4.8	3.0	4.4
	12	3.7	4.0	7.0	6.2	6.3	9.8	6.9
	Mean	3.7	4.3	6.4	6.4	6.3	8.0	8.5
	S.D.	1.7	2.0	3.1	3.0	2.5	2.8	2.2

Sample	Panelist	consis	spread	absorb	oiliness	shine	moist	soft
451	1	3.0	8.1	4.9	13.4	13.1	8.4	5.3
	2	5.9	6.7	8.1	4.8	5.1	10.6	8.2
	3	8.6	7.4	5.1	11.5	12.9	8.8	6.3
	4	6.3	9.8	2.9	10.7	9.1	11.6	11.2
	5	6.3	10.3	3.7	3.7	3.7	10.9	10.6
	6	8.3	8.3	5.9	6.4	6.3	8.8	8.6
	7	12.4	11.0	11.4	11.1	11.1	11.9	10.3
	8	11.4	5.3	6.2	6.9	4.5	5.4	7.8
	9	13.9	10.6	2.3	12.1	12.6	12.4	10.9
	10	8.6	7.9	6.0	8.9	9.7	6.9	6.9
	11	10.1	2.0	11.5	12.6	13.1	12.1	12.8
	12	8.6	7.8	3.7	9.2	7.6	9.4	9.2
	Mean	8.6	7.9	6.2	9.3	9.2	9.8	9.0
	S.D.	3.2	2.7	3.1	3.3	3.7	2.3	2.3

Sample	Panelist	consis	spread	absorb	oiliness	shine	moist	soft
307	1	7.3	7.3	5.9	7.7	8.1	10.1	2.2
	2	1.7	2.0	8.9	9.8	2.9	11.0	9.6
	3	2.1	2.1	4.9	5.5	6.5	8.3	5.8
	4	1.6	2.7	5.2	6.3	9.1	9.1	8.6
	5	2.5	11.9	2.7	2.5	2.7	7.0	2.2
	6	4.0	3.6	7.0	9.5	9.1	7.4	7.3
	7	3.7	3.4	3.4	9.2	9.6	11.4	9.6
	8	5.5	5.8	8.3	8.8	6.4	4.5	6.9
	9	1.7	1.8	8.7	6.2	5.6	10.7	13.4
	10	1.5	3.7	2.2	4.8	4.9	5.4	5.4
	11	2.0	.9	5.1	9.1	7.0	5.0	8.8
	12	2.6	4.4	5.5	7.3	6.3	8.5	7.0
	Mean	3.0	4.1	5.7	7.2	6.5	8.2	7.2
	S.D.	1.9	3.2	2.4	2.4	2.4	2.5	3.3

Sample	Panelist							
452	1	6.3	10.5	1.6	6.8	7.2	9.2	4.2
	2	2.2	3.1	7.3	9.1	5.1	10.1	7.9
	3	1.7	2.7	7.6	4.6	4.6	7.3	4.5
	4	1.6	2.7	5.0	3.9	9.1	7.2	8.6
	5	11.9	5.5	12.1	12.1	12.1	9.1	12.6
	6	3.2	5.1	6.5	7.3	7.3	6.7	9.2
	7	2.7	2.6	2.7	10.7	10.7	10.9	6.4
	8	6.5	5.8	7.6	8.1	7.6	4.5	6.9
	9	1.7	1.2	12.6	7.4	3.9	11.7	13.4
	10	2.5	4.4	2.7	4.0	4.0	2.5	2.5
	11	1.2	1.2	6.3	7.0	2.0	1.2	3.2
	12	3.6	2.0	6.3	4.7	6.5	7.0	8.1
	Mean	3.8	4.1	6.5	7.4	6.7	7.3	7.2
	S.D.	3.2	2.7	3.6	2.6	3.1	3.4	3.6

Sample	Panelist							
569	1	5.0	9.1	3.9	5.5	6.0	6.5	6.2
	2	6.3	7.8	10.1	5.3	2.2	9.1	7.3
	3	10.1	7.2	9.6	8.6	6.8	6.5	3.7
	4	4.9	5.8	9.5	3.9	4.1	8.1	8.6
	5	8.8	7.3	10.3	10.3	8.8	12.4	7.0
	6	5.8	6.3	8.1	5.3	5.5	10.1	9.6
	7	11.4	4.0	3.9	10.1	6.2	10.1	7.2
	8	9.8	3.6	5.8	5.1	3.7	4.0	6.3
	9	11.9	3.6	3.1	6.2	6.4	10.2	11.6
	10	7.2	11.5	1.5	6.3	7.8	3.2	3.2
	11	2.5	11.1	3.7	3.0	3.5	2.0	1.5
	12	7.1	6.8	6.0	7.1	5.8	8.1	6.9
	Mean	7.6	7.0	6.3	6.3	5.6	7.5	6.6
	S.D.	3.0	2.8	3.3	2.4	2.0	3.3	2.9

Sample	Panelist							
726	1	4.0	11.0	2.3	4.5	4.0	7.3	3.0
	2	3.0	3.4	9.3	5.5	3.2	8.6	6.7
	3	6.8	6.8	9.1	4.0	4.0	4.5	3.0
	4	4.9	1.8	7.0	3.9	4.1	7.2	7.6
	5	5.5	8.8	9.3	4.2	6.0	2.5	3.7
	6	6.5	6.9	8.7	4.5	4.8	9.6	10.1
	7	10.3	5.8	5.8	3.7	3.5	4.4	4.8
	8	9.1	4.2	7.6	4.2	3.0	3.0	5.3
	9	2.7	3.6	11.6	8.3	9.3	11.2	12.2
	10	5.9	9.8	5.0	7.0	7.0	4.1	4.1
	11	4.4	3.5	1.2	3.5	.9	2.5	2.0
	12	6.5	5.7	6.3	4.0	5.1	5.3	5.1
	Mean	5.7	6.0	7.0	4.9	4.5	5.9	5.7
	S.D.	2.4	3.0	3.2	1.5	2.2	3.0	3.2

APPENDIX 6.2 Sensory Attributes Scores Obtained from Panel Training

FIRST TRAINING

Sample	Panelist	Consis	Spread	Absorb	Oil	Shine	Stick	Moist	Soft
803	1	3.6	8.0	10.7	6.1	3.2	3.4	7.5	8.3
	2	3.9	6.3	8.6	3.1	2.4	2.5	7.8	8.6
	3	8.3	7.3	7.8	7.8	6.1	7.9	7.8	7.3
	4	6.6	4.6	5.5	4.1	3.9	8.2	7.5	9.3
	5	6.1	9.8	6.5	8.5	11.2	11.0	7.5	9.0
	6	7.3	7.3	9.0	7.0	6.6	6.4	9.1	9.4
	7	6.4	7.5	3.5	7.5	3.2	7.5	7.5	6.7
	8	7.4	6.2	10.7	3.4	2.5	7.5	7.5	9.1
	9	4.0	4.2	12.0	7.5	4.7	1.5	7.5	7.5
	10	2.4	2.7	4.4	3.8	3.7	3.6	6.0	7.5
	11	6.8	7.8	12.6	11.7	1.8	6.8	7.0	10.5
	12	7.5	10.4	3.4	6.2	4.5	12.7	6.2	5.7
	Mean	5.86	6.84	7.89	6.39	4.48	6.58	7.41	8.24
	S.D.	1.89	2.22	3.25	2.51	2.56	3.37	0.79	1.34

Sample	Panelist	Consis	Spread	Absorb	Oil	Shine	Stick	Moist	Soft
451	1	11.2	10.1	4.0	12.6	12.4	11.9	12.1	6.3
	2	10.6	7.0	6.2	7.8	7.8	10.1	5.6	6.1
	3	11.7	9.3	4.2	12.0	12.7	12.8	6.0	5.8
	4	10.0	9.7	4.3	11.2	11.0	10.6	6.5	7.3
	5	13.5	13.5	1.5	13.5	6.6	11.5	10.8	2.7
	6	11.3	6.8	6.7	11.8	11.3	11.6	7.0	6.6
	7	10.6	8.4	11.7	12.0	12.3	6.1	11.8	11.3
	8	11.3	11.6	3.2	12.1	11.4	8.9	9.9	10.2
	9	12.1	6.4	7.6	11.9	11.8	10.3	7.5	10.7
	10	9.7	8.4	7.7	10.5	11.1	13.0	9.7	8.2
	11	10.3	9.2	5.2	10.3	12.7	11.9	12.2	7.3
	12	10.7	9.5	7.6	10.8	10.9	10.7	7.6	4.7
	Mean	11.08	9.16	5.83	11.38	11.00	10.78	8.89	7.27
	S.D.	1.03	2.03	2.69	1.44	1.91	1.88	2.47	2.52

Sample	Panelist	Consis	Spread	Absorb	Oil	Shine	Stick	Moist	Soft
307	1	4.5	10.1	5.1	10.8	10.4	10.7	11.3	6.3
	2	2.9	3.9	8.3	17.3	3.0	9.5	7.2	7.4
	3	4.8	3.2	8.0	7.9	6.9	8.5	7.2	7.0
	4	3.0	3.0	5.5	7.3	8.6	9.4	6.5	7.3
	5	1.5	1.5	10.1	5.4	13.5	8.7	13.5	13.5
	6	4.3	4.1	11.2	8.9	8.2	8.3	10.9	11.1
	7	3.1	3.4	4.3	4.2	4.4	8.7	10.4	8.4
	8	3.4	2.7	11.7	8.7	5.3	4.0	11.5	10.2
	9	1.5	1.5	13.6	2.4	2.8	1.5	4.2	7.5
	10	4.7	4.9	6.9	8.4	9.0	10.6	8.5	6.9
	11	2.3	2.2	10.8	4.3	7.2	8.4	9.9	12.1
	12	6.3	2.6	12.9	5.1	3.4	3.9	10.1	7.5
	Mean	3.53	3.59	9.03	7.56	6.89	7.68	9.27	8.77
	S.D.	1.44	2.28	3.14	3.92	3.27	2.92	2.60	2.36

APPENDIX 6.2 (CONTINUED)

SECOND TRAINING

Sample	Panelist	Consis	Spread	Absorb	Oil	Shine	Stick	Moist	Soft
803	1	6.7	8.4	6.4	8.1	9.0	8.6	9.7	7.5
	2	6.8	4.2	9.7	6	4.3	5.8	9.1	7.1
	3	3.9	4.1	6.4	6.4	6.4	5.4	8.3	6.9
	4	3.7	3.4	6.3	4.5	3.5	8.4	9.3	8.4
	5	4.7	3.3	2.9	6.2	6.4	8.4	8.2	8.9
	6	5.9	5.8	8.4	6.6	7.3	7.1	9.4	9.3
	7	7.3	5.0	10.8	6.5	6.6	2.9	9.5	8.9
	8	8.9	3.2	6.2	10.7	3.0	7.5	7.5	4.5
	9	3.5	3.9	7.5	4.0	2.8	4.1	7.5	7.5
	10	7.0	3.0	8.8	3.8	5.7	4.5	8.9	8.9
	11	7.2	8.6	6.5	2.3	2.5	6.2	7.2	10.7
	12	7.5	2.0	7.5	2.5	1.5	7.5	4.5	7.5
	Mean	6.1	4.6	7.3	5.6	4.9	6.4	8.3	8.0
	S.D.	1.7	2.1	2.0	2.4	2.3	1.9	1.5	1.6

Sample	Panelist	Consis	Spread	Absorb	Oil	Shine	Stick	Moist	Soft
451	1	11.8	7.6	7.9	10.8	11.9	10.7	7.5	6.8
	2	11.2	9.1	6.9	10.7	7.9	9.5	7.8	5.9
	3	11.2	11.2	8.5	10.7	12.1	11.6	8.9	8.9
	4	11.1	7.9	5.1	11.9	11.8	7.5	7.1	9.8
	5	8.2	10.1	7.1	3.3	10.7	11.6	5.7	5.1
	6	11.0	7.5	6.4	10.5	10.6	5.5	0.2	10.1
	7	13.2	6.5	12.6	11.6	11.9	9.9	12.2	11.1
	8	13.5	10.5	7.5	11.9	10.9	10.8	10.2	10.4
	9	11.1	5.2	7.5	10.3	10.3	5.4	8.6	8.8
	10	11.3	7.8	3.7	11.5	12.5	11.3	7.5	11.3
	11	12.8	12.6	7.7	11.5	13.1	12.0	11.7	7.8
	12	10.4	10.7	8.5	13.5	13.5	10.7	2.7	5.8
	Mean	11.4	8.9	7.5	10.7	11.4	9.7	8.3	8.5
	S.D.	1.4	2.2	2.1	2.5	1.5	2.3	2.6	2.2

Sample	Panelist	Consis	Spread	Absorb	Oil	Shine	Stick	Moist	Soft
307	1	4.6	3.9	7.9	9.5	10.2	10.0	7.5	6.8
	2	5.4	2.6	10.1	9.0	6.3	8.2	6.1	6.6
	3	3.2	3.4	6.7	6.5	5.7	6.2	8.2	7.4
	4	1.8	2.6	7.1	9.0	9.6	8.4	8.1	9.8
	5	2.8	5.2	10.6	7.2	7.2	6.3	9.5	12.2
	6	3.6	3.5	7.5	7.7	7.5	6.4	8.0	9.8
	7	2.9	3.0	9.6	8.0	8.0	8.2	10.7	6.6
	8	4.7	2.5	5.5	9.6	3.6	6.2	8.9	3.8
	9	1.5	1.5	5.0	2.8	1.9	2.5	9.7	7.5
	10	9.6	5.6	6.3	8.8	9.4	8.1	11.5	10.2
	11	1.8	2.1	10.3	6.0	6.4	4.1	9.5	6.6
	12	5.3	1.5	13.5	1.5	2.5	4.5	9.7	10.6
	Mean	3.9	3.1	8.3	7.1	6.5	6.6	9.0	8.2
	S.D.	2.2	1.3	2.5	2.6	2.7	2.1	1.5	2.4

APPENDIX 6.2 (CONTINUED)

THIRD TRAINING

Sample	Panelist	Consis	Spread	Absorb	Oil	Shine	Stick	Moist	Soft
803	1	11.2	11.8	8.6	3.2	2.8	3.4	7.5	7.5
	2	3.6	5.9	7.0	4.7	3.0	7.2	8.7	8.3
	3	6.5	3.4	7.9	7.0	4.8	5.8	8.5	8.1
	4	3.2	3.3	8.8	3.7	4.8	7.2	7.3	8.7
	5	6.5	4.0	6.4	6.7	5.3	8.2	7.8	8.6
	6	2.9	3.5	11.3	3.6	4.5	7.1	9.1	6.3
	7	7.0	4.2	7.5	4.4	4.6	7.9	4.3	8.7
	8	7.5	5.4	11.1	5.3	5.0	10.0	6.2	5.9
	9	7.5	5.2	8.8	6.1	4.5	4.2	7.5	3.9
	10	7.5	3.4	8.6	4.3	4.7	5.5	8.2	8.3
	11	6.9	7.6	6.0	5.3	2.8	6.7	7.1	8.2
	12	7.3	3.2	7.1	2.9	1.9	6.9	5.1	6.9
	Mean	6.5	5.1	8.3	4.8	4.1	6.7	7.3	7.5
	S.D.	2.3	2.5	1.7	1.3	1.1	1.8	1.4	1.5

Sample	Panelist	Consis	Spread	Absorb	Oil	Shine	Stick	Moist	Soft
451	1	11.9	12.8	5.8	9.7	8.4	8.4	6.5	6.5
	2	8.6	8.5	10.7	7.9	6.4	8.2	9.6	8.9
	3	9.9	11.4	8.1	10.9	12.0	10.0	7.2	7.0
	4	11.4	7.8	4.9	11.7	11.6	11.0	8.9	7.9
	5	8.5	7.1	7.5	8.3	10.2	6.5	5.6	6.3
	6	10.8	9.0	5.5	11.0	11.7	9.8	6.9	7.9
	7	11.3	5.3	10.4	12.1	12.0	8.7	9.5	9.4
	8	13.5	1.1	5.4	11.9	11.9	11.6	8.7	11.5
	9	11.1	10.6	7.5	8.9	8.4	7.5	9.1	6.4
	10	11.9	7.5	5.7	11.2	12.9	11.6	7.6	9.5
	11	12.3	11.8	8.5	11.4	13.4	13.8	12.7	8.5
	12	9.8	10.6	8.9	12.9	12.8	13.7	12.5	6.6
	Mean	10.9	8.6	7.4	10.7	11.0	10.1	8.7	8.0
	S.D.	1.5	3.2	2.0	1.6	2.2	2.3	2.2	1.6

Sample	Panelist	Consis	Spread	Absorb	Oil	Shine	Stick	Moist	Soft
307	1	10.6	6.5	6.6	8.7	2.8	3.9	7.5	7.5
	2	2.6	8.3	11.7	5.6	3.0	7.6	9.2	8.3
	3	5.3	2.6	8.3	5.2	4.2	6.2	7.8	7.6
	4	2.2	1.9	7.5	8.3	8.2	8.9	10.0	9.5
	5	4.3	5.6	7.8	7.6	6.9	6.8	8.9	12.8
	6	1.8	1.8	12.3	5.0	4.9	6.7	8.5	9.7
	7	5.3	3.4	9.1	3.7	3.8	7.2	7.5	10.3
	8	6.8	4.5	11.9	6.0	2.9	8.9	6.2	7.5
	9	3.8	2.5	5.0	7.5	6.7	4.2	10.4	6.4
	10	4.5	6.2	6.8	7.8	8.9	7.8	11.8	11.5
	11	3.3	3.2	11.0	6.8	7.8	6.5	10.7	9.3
	12	5.6	2.7	12.8	7.4	3.5	4.8	10.3	10.3
	Mean	4.7	4.1	9.2	6.6	5.3	6.6	9.1	9.2
	S.D.	2.4	2.1	2.6	1.5	2.3	1.6	1.6	1.9