SENSORY EVALUATION OF

NEW ZEALAND COMMERCIAL WHOLE MILK POWDERS

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HESTER REBECCA COOPER
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ABSTRACT

Whole milk powder is a multi-million dollar export earner for New Zealand. Over recent years, there has been a change in emphasis for whole milk powder from a commodity to a consumer product. This has made it increasingly important to understand its sensory properties which are essential to ultimate consumer acceptance.

A sensory profile for New Zealand whole milk powders was established in a systematic fashion through group discussions using a trained panel. The final profile included thirty-two attributes to describe the appearance, aroma, flavour and texture of both powders and reconstituted milks.

Three different sensory scales were used in association with the profile throughout one dairying season. These were a 0-10 linear scale, a semi-structured linear scale and magnitude estimation scaling. A comparison was made of these three scales according to usage factors and their sensitivity to differences between samples. The semi-structured linear scale was the easiest scale to use but was not very sensitive to sample differences. Magnitude estimation was not sensitive to sample differences and there were problems associated with its usage. The 0-10 linear scale was easy to use and sensitive to sample differences.

Relevant sensory data from one complete dairying season were compared with data from instrumental measurements of colour and texture made on both powders and reconstituted milks. Reflectance measurements made using a Hunterlab D25 colorimeter and calculated indices of the particle size distribution were the only measurements which related closely to sensory properties of whole milk powders.

The effect of seasonal changes in the sensory properties of whole milk powders was studied over two dairying seasons. Highly significant seasonal changes occurred in physical properties of whole milk powders, such as colour. In the aroma and flavour of both powders and reconstituted milks, the most significant seasonal changes were in the sweet, buttery and cooked/caramelised notes. Changes were greatest at the beginning and end of the dairying season.

The effects of certain processing variables on the sensory properties of whole milk powders were also studied. Processing variables which changed the physical structure of the powder were found to have a highly significant effect on colour, free-flowing properties and particle size. Addition of vitamins and minerals had a highly significant effect on the aroma and flavour of both powders and reconstituted milks. This was confirmed by data from experimental powders containing controlled levels of vitamins and iron which were made at the New Zealand Dairy Research Institute. Powders containing vitamins and iron were characterized as 'lactone-like', 'vitaminized' and 'oxidised'. Changes in the aroma and flavour characteristics were much greater in instantized powders. Some of these effects were thought to be associated with oxidation of soybean lecithin in these particular powders.

Using a simplified version of the profiling method established in this project, it should be possible to match products to market requirements far more effectively than the present single score grading system.

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CHAPTER I

INTRODUCTION

Whole milk powder is an export product of increasing importance to New Zealand. Over 60 000 tonnes of whole milk powder and related products were produced during the 1979/80 dairying season and production is expected to reach 100 000 tonnes within the next three years (Menzies 1981, personal communication). The quantity of powder being packed for direct use by the consumer is increasing rapidly. The New Zealand Dairy Board expects to pack 30 000 tonnes of whole milk powder for consumer use by the 1982/83 dairying season. This change, from a commodity to a consumer product, has placed an increasing importance on the consumer's reaction to whole milk powder.

A consumer's evaluation of the quality of any food product is based mainly on its sensory properties. The colour and appearance of both package and product are the first properties evaluated by the consumer. The aroma of the product will then be evaluated followed by flavour and texture. The consumer, in accepting or rejecting a product, makes an integrated assessment of all these sensory properties. A consumer evaluates whole milk powder in the same way, yet there is no documentation as to which sensory attributes are important in consumer acceptance. Indeed, there has been no detailed characterization of the sensory properties of whole milk powder.

The colour of milk and milk products is important because it is the first sensory property to influence a consumer's decision to accept or reject the product. For example, dark-coloured dairy products have often been considered old or inferior, whereas these colour differences may be due to natural variation. Previously, the measurement of colour in dried milk products was often neglected, although more recent workers have begun to study this property, particularly as it is perceived by the consumer. However, there is still very little information on the way in which both seasonal changes and different processing methods affect this important sensory property.

The aroma of dried milk products is not well defined, either as powders or as reconstituted milks. Some work has been done to isolate compounds responsible for 'feedy' and 'cowy' aromas but otherwise there has been little work reported. Milk powder has a distinctive aroma and gross changes in the product will be obvious to the consumer, the aroma of the powder being evaluated even before reconstitution.

The flavour of whole milk powder has been studied extensively. Interest in the flavour of milk powders has centred around storage trials. Flavours which arise in milk powder have been termed 'off-flavours', placing an immediate quality judgement on such flavour changes. Little or no attempt has been made to characterize the flavour notes of either fresh or stored milk powder and to relate these characteristics to changes in processing methods or seasonal variation.

The textural characteristics of whole milk powders have not yet been fully explored. Some study has been made of the flow properties of milk powders, particularly as these relate to powder handling during storage and subsequent shipping. However, there have been few studies of these flow properties as they relate to consumer perception of the textural appearance of milk powders. Recent studies have indicated that these flow properties are important to the consumer, influencing expectations for a particular milk powder (Baldwin 1977).

The texture or mouthfeel of the reconstituted milk is another area in which there has been little study, although the mouthfeel of any liquid is an important sensory property. The behaviour of dispersion systems, such as reconstituted milk, falls into the study of rheology of suspensions and emulsions. Although the rheology of fresh milk has been studied in some depth, that of reconstituted milk has not. There is a need for study in the important sensory properties of texture and mouthfeel in reconstituted milk powders.

For the complete study of whole milk powders, a sensory method is required which will produce an integrated picture of all these sensory properties. Sensory profiling techniques offer the most scope for the complete characterization of whole milk powders. This sensory method identifies all the sensory attributes in a product and measures the intensity of individual attributes.

The first sensory profiling techniques produced detailed descriptions of products but no quantitative data. Later workers, such as Szczesniak et al. (1963), used scaling methods with profiling techniques to produce data suitable for statistical analysis. In the past, the choice of scaling method for use with these sensory profiling techniques appears to have been rather an arbitrary one. Category, semi-structured linear and ratio scales have all been used. Each of these three scaling methods has its own particular advantages and disadvantages. Provided that satisfactory methods or validation and analysis can be found, all three methods potentially offer an acceptable scaling procedure for use with sensory profiling.

One of the more traditional scaling methods which has been used in the dairy industry over many years is the 'category' or 'interval' scale. The commonest form of this scaling method is the scoring method in which sensory attributes are scored on an established numerical scale. These scoring methods are among the most frequently used sensory methods because of their diversity, simplicity and apparent ease of statistical analysis. A slightly different method of scaling for sensory profiling techniques has been suggested by Stone et al. (1974). These workers used a semi-structured linear scale anchored by descriptive terms at each end. Baten (1946) had shown that this type of scale was more sensitive to product differences than a conventional category scale. This semi-structured scale represents a step forward from the category scale but it is still not possible to relate the sensory results directly with experimental variables. Indirect relationships only can be sought with both category and semi-structured scales. For a number of years, experimental psychologists have been using a procedure known as magnitude estimation to produce a scale which can be used to relate changes in sensory properties to changes in manufacturing variables. In magnitude estimation, the panelist scales the intensity of each sample in terms of a reference. The idea is to place stimuli on a scale so that one stimulus can be rated as a specified number of times stronger or weaker than the reference. Because sensory profiling had not previously been used to evaluate whole milk powders, there was no indication as to which scaling method would be most effective in measuring the sensory attributes.

Sensory profiling techniques are not suited to the routine testing of whole milk powders. Because of this, a number of empirical objective tests for colour and texture were made in parallel with the sensory testing. Highly complex chemical analyses of aroma and flavour compounds or complex measurements of colour and texture were considered to be outside the scope of this study. It was felt to be more applicable to the industry to study the sensory data in relation to simple functional tests which could be utilized by commercial companies. It was hoped that relationships between sensory and instrumental tests would be sufficiently close to allow the substitution of instrumental tests for the measurement of certain sensory properties.

There was a need to study the sensory properties of a variety of commercial New Zealand whole milk powders so that the important characteristics could be identified. These sensory properties change during the dairying season, they change due to processing conditions and there are differences between different specification powders. It has been recognised for many years that significant changes occur in milk as the pasture changes during the dairying season. These changes in the milk are carried through into the various dairy products and are particularly noticeable in fat-containing products, such as whole milk powder. The effect of these seasonal changes upon the sensory properties of New Zealand whole milk powders has never been evaluated. In addition to naturally occurring seasonal changes, it has long been recognised that different processing conditions also significantly affect the properties of whole milk powders. Today, whole milk powders often contain additives to provide for the requirements of different customers. A wide range of milk powders of differing specifications are manufactured each year. There is no indication whether the additives, such as vitamins and minerals, have a significant effect on the sensory properties. Therefore, there was a need to characterize the sensory properties of the different powders being produced by the New Zealand dairy industry throughout the dairying season.

The aim of this project, therefore, was to study in some detail the sensory properties of a wide variety of commercially produced New Zealand whole milk powders from five factories over a period of two dairying seasons. Within this aim, there were a number of objectives:

1. To establish a profile of the sensory properties of commercial New Zealand whole milk powders. In order to do this, attributes of colour, aroma, flavour and texture in both powders and reconstituted milks had to be identified and described.

2. To study the effectiveness of different scaling methods for evaluating differences in the sensory profiles of whole milk powders.

   To do this, a 0 - 10 linear scale, a semi-structured scale and magnitude estimation scaling were compared throughout one dairying season.

3. To study the relationship between certain sensory attributes in milk powders and empirical objective measurements for colour and texture made on the same powders.

   Reflectance measurements of colour were made on the powders and the total colour (expressed as β -carotene) was measured spectrophotometrically. Sieve analyses were done to characterize the particle size distribution of the powders. Viscosity measurements were made on the reconstituted milks using both a capillary viscometer and a cone and plate viscometer. Relationships between these objective measurements and the relevant sensory properties were then studied.

4. To investigate the effect of seasonal changes upon the sensory properties of New Zealand whole milk powders.

   Commercial New Zealand whole milk powders were studied over a period of two dairying seasons, to evaluate the way in which seasonal changes affected the sensory properties.

5. To study the effect of processing conditions on the sensory properties of New Zealand whole milk powders.

   Powders were studied from five different factories, producing both agglomerated and non-agglomerated powders. The effects of these different processing conditions were then studied.

6. To investigate possible differences in the sensory properties of different specification milk powders and to find possible explanations for these differences.

   Twenty three different specification powders were tested during the two dairying seasons. Data from these powders were studied to evaluate the differences in sensory properties between different specification powders. During the 1979/80 dairying season, it was found that the addition of vitamins and minerals had a significant effect on the sensory properties of whole milk powders. Experimental work was carried out to define changes in the sensory properties caused by these additives.

CHAPTER II

REVIEW OF SENSORY EVALUATION LITERATURE

1. INTRODUCTION

In measuring the sensory properties of any product, a suitable sensory method for evaluation is needed. For this study, in which many different sensory properties were to be measured simultaneously, special techniques were required. From a preliminary search of the literature, it was clear that descriptive sensory techniques offered the most flexibility for the project. Once a sensory technique has been found, it is necessary to find a suitable scaling method to accompany it. Category, semi-structured linear and ratio scales were all reviewed as to their ease of use and suitability. All sensory scaling methods currently used in sensory analysis have advantages and disadvantages. No scale presents a complete or ideal answer to the sensory evaluation worker. In deciding which scale is to be used, the disadvantages of a particular scale must be taken into account both in the setting up of the study and in the analysis of the resultant data.

2. DESCRIPTIVE SENSORY ANALYSIS

Descriptive sensory analysis has proved a valuable tool in that it provides a complete description of sample differences in a relatively short time. At one time, it was thought that panelists could not evaluate several sensory characteristics in a product without becoming confused. However, work in this area has shown that this type of sensory analysis can give extremely valuable information about a product. The training of profile panels requires considerable time and members must possess a high degree of motivation and interest. Once trained, however, the panel can provide thorough and reliable descriptions of products in a short time (Larmond 1976). This type of 'profiling' technique can be expanded to cover all the major sensory attributes which is particularly valuable when these properties are vastly different.

Any type of sensory analysis, be it simple difference test or more complex profiling techniques, relies upon some method of sensory scaling. The act of scaling requires the panelist to assign numbers to product attributes which reflect his or her perception of their relative intensities. Although descriptive sensory methods have considered many factors involving the sensory properties of a product, relatively little attention has been focused on the way in which these attributes are scaled. Generally, category scales of one type or another have been used. Szczesniak et al. (1963) felt that they had produced a linear scale with their use of standard reference products to represent each point on the scale. However, such a system is open to some change as commercial products alter in both their textural properties and their availability. There still remains some doubt as to whether this type of scale is truly linear in nature or whether 'end effects' still occur, even with the use of reference points. The semi-structured linear scale which Stone et al. (1974) used with descriptive sensory techniques represents a step forward from the traditional category scale but is still not entirely free of difficulties, such as 'end effects'. The use of ratio scaling has been suggested in association with profile techniques to remove the difficulties inherent in the use of category and semi-structured linear scales. This suggestion is sound, provided that a true ratio is produced.

3. CATEGORY SCALING

3.1 Method

A category scale is created when observers assign a category to a series of stimuli. This category may be designated by a descriptive term, a number or letters of the alphabet. The number of categories used makes little difference to the form of the category scale (Stevens 1975). Category methods of scaling require the panelist to assign numbers etc. to stimuli so that the interval or distance between ratings reflect the differences between the products for the attributes being scaled. Because of its simplicity as a scale to measure magnitudes, the category scale has found wide acceptance for relating physical intensity to judgement intensities (Moskowitz 1977a).

There are a number of considerations when using these scales. The number of categories must not be too small nor too large. If the number of categories is too large the panelist loses his concept of relative magnitude on the scale. If the number of categories is too small then the scale will not be sensitive enough to detect changes in the intensity of sensory attributes (Moskowitz 1977a). In general, it is thought that people can assign stimuli to only about five to seven categories (Amerine et al. 1965). Larmond (1977) has also pointed out that to use these scaling methods effectively all the panelists must evaluate the same characteristic. This is not a problem when a simple characteristic, such as sweetness, is involved but when a complex characteristic is being evaluated, such as the texture of French fries, panelists may not all have the same concept.

Amerine et al. (1965) believed that during the initial training period, judges orient themselves to the range of quality attributes in the commodity, use descriptive terms to anchor their own evaluations, then proceed to score numerically, utilizing a linear scale. If the descriptive and numerical terms are assumed to represent equal sensory intervals, the scales may be regarded as being linear. Assuming a linear scale, analysis of variance can be used to give an indication of any significant differences between samples. Multiple range tests, such as Tukey's test, can then be used to determine where those differences lie.

Statistical analyses of data from category scales are based upon the assumption that scores are normally distributed, categories are equally spaced and scores are proportional to the variation in the attribute being measured (Cloninger et al. 1976). This assumption of normality may not always be valid and there is the possibility of inaccurate statements concerning probability of significance in F- and t-tests. Cloninger et al. (1976) suggested methods of data transformation to achieve normality. These workers used Guilford's method of normalizing categories based on the z values (Guilford 1954). The procedure provides a normalized scale for the data. The new category widths reflect the size of the categories on the psychological continuum and the ability of judges to discriminate at any point on the scale.

3.2 Advantages

Category scaling methods have been widely used for many years because of their diversity and ease of use. Category scales are attractive procedures for measuring sensory intensities, as they are conceptually simple for both the experimenter and the panelist. In addition, they are reported to give valid and interpretable numbers which reflect sensory magnitudes.

Guilford (1954) felt that category scale methods had certain definite advantages. For one, these methods require much less time than paired comparison or ranking methods. Category scale methods have a very wide range of application and they can be used with panelists who have had a minimum of training. These methods can be used with large numbers of stimuli although they become difficult when there are more than thirty to forty stimuli to be evaluated. In addition, these scales are easily explained to panelists and the scale values can be easily used in a host of statistical analyses (Moskowitz 1977a).

3.3 Disadvantages

One of the difficulties encountered in the use of category scales is their instability or tendency to drift in meaning with time and with judges. Tarver and Schenck (1958) suggested that to prevent the subjective scoring scale from drifting, the scale be anchored to known physical measurements. The relationship between objective and subjective scales is easily determined by statistical methods and the precision of quality judgements can be assessed in a similar manner. Another disadvantage of category scaling is that it sets a limit on the numbers, letters or adjectives an observer is allowed to use. The observer must try to spread a limited, finite set of numbers over whatever range of stimuli is presented to him or her. In other words, whenever the experimenter limits the numbers, the observer's response lapses into a partitioning operation (Stevens 1975).

The terms on the scale are assumed to represent equal sensory intervals and the scales are regarded as being linear. These assumptions are sometimes violated. For instance, one cannot be sure that the distance between 'slight' and 'moderate' is the same as the distance between 'strong' and 'intense'

(Larmond 1976). It also appears to be quite possible that the category scale is not a true interval scale. If a category judgement is determined solely by the magnitude of the stimulus, the judgement should be completely independent of the values of other stimuli presented. Results have shown that there is a strong tendency for observers to assign the stimuli to categories in such a way that all categories are used about equally often (Gescheider 1976). It has also been shown by Stevens and Galanter (1957) that panelists shy away from using the end categories and the 'category and effect' biases the ratings. This has been confirmed by McBride (1980).

The question of validation for these scales remains a vexed one. It has been suggested that intervals are psychologically meaningless and that the numbers used as scale values do not lie in the field of real numbers where both addition and subtraction are possible. However, it has been demonstrated that observers are capable of performing addition and substraction of subjective magnitudes consistently using ratio scaling. Obviously, there is something in the task of category rating which observers conceive of in a different way from ratio scaling. Eisler (1963) believed that the observer regarded category scaling as a task of discrimination rather than as a means of scaling subjective magnitudes.

Because there are end points for the category scale, it does not parallel the true interval scale used by physicists in temperature assessments. Those latter interval scales contain no boundaries, whereas category scales contain both an upper and a lower boundary. The category scale leads to biases in judgements. Panelists may not be sure of the range of stimuli and become conservative in assigning numbers. This will bias the ratings and the bias may become severe if a series are bunched at one end of the continuum (Moskowitz 1977a). In general, category methods give non-linear scales whenever panelists' sensitivity to differences, measured in subjective units, is not constant over the scale. Only when sensitivity is uniform over the continuum can linear results from category ratings be expected.

4. SEMI-STRUCTURED LINEAR SCALE

4.1 Method

Stone et al. (1974) used a semi-structured linear scale in their proposed quantitative descriptive analysis (QDA) system. The selection of the most appropriate scale for measuring sensory responses was considered basic to the development of their profiling technique. The choice of scale was influenced by Baten (1946) who showed that a scale word-anchored only at the ends yielded greater product differences than the typical category scale. Stevens (1957) had clearly shown that it was possible for individuals to make direct assessments of subjective magnitude for perceived sensory attributes. The use of category scales for judgements was discarded by Stone et al (1974) because of the difficulties inherent in such scales. An interval scale was used which consisted of a line of specific length (6 inches long) with anchor points half an inch from each end and usually, but not always, with a third anchor point at the midpoint. One word or expression was placed at each anchor point. The subject had the task of placing a vertical mark across the line at the point which best reflected the magnitude of his or her perceived intensity of that particular attribute (Stone et al. 1974). Weiss (1972) used a similar method which he called 'graphic rating' except that his panelists were provided with reference stimuli at each test session.

Larmond (1976) described this method as one which combines descriptive analysis and ratio scaling in that the unstructured line does not constitute an interval scale since the intervals are not marked. Stone et al. (1974) felt that this type of scaling yielded data appropriate to the statistical model and consistent with what would be predicted with an equal-interval scale. These workers observed that the use of this scaling technique was consistent with the analysis of variance model and enabled them to develop a computer program to determine subject performance, repeatability and related analyses in addition to the basic issue of product difference. However, there has been little published literature to support this claim and whether this scale should be used as though it were an equal-interval scale requires further validation.

4.2 Advantages

The semi-structured linear scale, described by Baten (1946) marks a distinct improvement on the traditional category scale. The panelist has much greater freedom of choice as to how he or she expressed his or her sensory impressions. This method of scaling is one which is conceptually easy for many panelists to grasp, merely requiring them to mark their immediate sensory impression of an attribute on the line.

Mecredy et al. (1974) showed that the use of his scale increased the efficiency and statistical reliability of their conventional profiling programme. The use of this scale yielded quantitative data to which statistical analysis could be applied providing a greater understanding of sensory differences between samples. Larson-Powers and Pangborn (1978) believed that anchoring the scale to a reference and expressing results in terms of positive or negative deviation from the reference improved both precision and accuracy of the response compared to an unanchored scale. Additional advantages of this anchored scale included the provision of an internal measure of judge reliability by comparison of the reference against itself as a blind sample and a fixed criterion of comparison to minimize drifting of responses with time. In product matching or product formulation, this method provided a quick measure of attributes and hence ingredients which needed to be increased or decreased relative to a fixed reference.

4.3 Disadvantages

In terms of measurement theory, the use of this method produces an interval scale which differs from the traditional category scale in that there are almost an infinite number of different positions on the line from which the panelist can choose. Like the traditional category scale, there are boundaries, so that the panelist's ratings cannot be as high as he or she wishes in order to reflect ever-increasing levels of an attribute. The existence of boundaries also brings into play the 'end effects' bias discussed by Stevens and Galanter (1957). When confronted with boundaries, panelists will shy away from extremely high ratings for fear of running out of numbers or line positions. This 'end effect' may cause statistical problems because the interval properties may fail to hold for the ratings at the end points of the scale.

5. MAGNITUDE ESTIMATION SCALING

5.1 Method

Category scales give information about the differences of magnitudes. For the food technologist, it would be helpful to develop a series of mathematical equations which would indicate proportional adjustments in ingredient levels needed to make a stated change in the sensory properties. For a number of years, experimental psychologists have been using a procedure known as magnitude estimation, to produce a scale which has these desired ratio properties (Moskowitz 1974).

Numerical estimation of sensory intensity by free number magnitude estimation of free number matching was espoused by Stevens (1960). This form of scaling was developed at Harvard University, in the psychaccoustic laboratory, to assess the relation between physical intensity and perceived magnitude of brightness and loudness. It was work by Stevens (1960) which first showed that, for more than a score of sensory continua, the apparent or subjective magnitude grows as a power function of stimulus intensity. He showed that a power function;

$$S = kI^n$$

relates sensory intensity S to physical intensity I. In log-log co-ordinates, the power function becomes a line,

$$\log S = n \log I + \log K$$

with slope n and intercept k. The exponent (slope n) characterizes the transformation of stimulus ratios into sensory ratios and is independent of the absolute physical intensities of the stimulus and of the modulus of the scale. The intercept k is the scale factor and may change from experiment to experiment without affecting the exponent (Moskowitz 1970).

The power function provides several important tools for the assessment of foods through sensory evaluation. It tells the product specialist a number S which reflects the sensory judgements to be expected from adding a given amount of ingredient I to the product. The exponent has a great deal to do with the way individuals transform ratios of ingredients to ratios of sensory magnitudes. If the exponent n exceeds 1.0 then sensory ratios are greater than the physical ratios (Moskowitz 1974).

With the magnitude estimation procedure, the panelist is instructed to assign to the first sample a number which may either be chosen beforehand by the experimenter or left to the discretion of the panelist and then to assign numbers to the remaining samples so that the ratios among the numbers reflect the ratios of the magnitudes perceived. The goal of the scaling procedure is to place stimuli on a scale so that one stimulus can be rated as a specified number of times stronger or weaker than a reference stimulus. No high or low limits are specified, one aim of the method is to have panelists measure in the same way that nature measures - with ratio scale values that have no arbitrarily limited endpoints (Moskowitz 1974).

Because the judge is unconstrained as to the range and size of his numbers, the scale that emerges has the properties of a ratio scale of magnitude. Thus, the size of the numbers that each panelist uses does not influence the scale, rather the ratios between his or her numbers convey information. The starting stimulus may be any member of the stimulus sequence and, except for some minor biases, the form of the ratio scale will be relatively unchanged (Moskowitz and Sidel 1971).

Since the magnitude estimation scale is unfettered in terms of scale points, the selection of the first stimulus is important. The first sample may be randomly selected, such that each panelist has a different starting stimulus. This should not affect the ratios of magnitude estimates for numbers assigned by one individual but will affect the actual numbers the panelists use. The first stimulus may be fixed and lie in the middle of the range. This alternative is sometimes preferred if panelists are unpracticed and if the range of stimulus variation is large. The numbers that panelists assign for the first stimulus can be fixed (fixed modulus) or free to vary (free modulus). The fixed modulus method, like the fixed standard method, often leads to characteristic clustering and over-representation of certain numbers (Moskowitz 1977b).

In the analysis of the data from magnitude estimation, the experimenter is faced with variation in the data due to the initial choice of the number and variation due to true individual differences in perception. The former variation can be eliminated by normalization of the data. Normalization refers to methods which are used to bring into common the scales that different individuals use. Normalization of the data is most commonly carried out by modulus equalization in which all the responses of the panelist are multipled by a single value. Although the absolute values of all the numbers are changed, the ratios among numbers remain unchanged. Each panelist is assigned his or her own unique correcting factor which multiplies each of his or her judgements. Modulus equalization does require that all panelists have evaluated all stimuli an equal number of times and that there have been no zeros in the ratings.

Magnitude estimates are distributed log normally, not normally. This means that the distribution of the magnitude estimates themselves is skewed upwards and that the majority of the numbers are at the lower end of the number range. Log normal distributions require that the geometric mean be used as the measure of central tendency and this has been done traditionally when using this scale (Moskowitz 1977b).

5.2 Advantages

Magnitude estimation has great appeal to those concerned with practical scaling problems, partly because of its simplicity and partly because of the regularity with which a power function describes sensory data. One of the main benefits of this scaling is the fact that the data it produces fit well into known statistical models. Statistical analysis of these numbers can be carried out using such techniques as analysis of variance, regression analysis etc. with much greater confidence than can be carried out on category scaling data.

5.3 Disadvantages

Magnitude estimation procedures were originally developed for the analysis of 'pure' stimuli. However, food products consist of many constituents and in situations, such as these, where the procedure must be used to 'average' a number of stimuli Weiss (1972) felt there was serious doubt in the validity of magnitude estimation as a response technique. He believed that magnitude estimation produced a bias in the panelists' response. Moskowitz and Chandler (1977) pointed out that for food products it was impossible to establish laws governing relationships between product constitution and consumer perception of a specific property.

Doehlert (1968) believed that magnitude estimation was a difficult task to ask of panelists, requiring memory of the sensory intensity of an attribute in the previous sample. He believed that estimates were affected by the intensity of recent samples but failed to point out that this occurs in many sensory scales. Researchers, such as Cross (1973), have found that there are sequential dependencies in magnitude estimation, just as there are in any other type of scaling. If there is only a fixed sequence of stimuli, then some part of the ratings will be ascribable to the sensory variations and respondents' perceptions while the other part will be biased, owing to contrast and convergence effects. In order to reduce the sequential dependencies and to prevent undue influence by one stimulus on the ratios for another, the usual remedies are to totally randomize the order of stimuli and collect more than one replicate rating i.e. present the same stimulus to the panelist on several occasions.

6. SUMMARY AND CONCLUSIONS

Sensory profiling techniques offer the most scope for the complete characterization of whole milk powders. This type of sensory technique can give a complete sensory assessment of a product in a relatively short time. Any type of sensory technique relies upon some method of sensory scaling. All of the scaling methods reviewed have their advantages and disadvantages, no single method offers the perfect solution for sensory evaluation.

Category scaling methods have been widely used for many years because of their diversity and ease of use. However, the question of validation remains a vexed one. Provided that analysis of category rating scales can take into account the inequalities found in sensory rating scales, these scales can be used with some assurance. However, it seems a somewhat dangerous practice to use these scaling methods in regular testing while ignoring their inconsistencies and assuming a linearity in the scale which has been shown to be false. Such practices can only lead to faulty interpretation of sensory data.

The semi-structured linear scale represents a considerable step forward from the category scale but there still appear to be some problems associated with 'end effects' at the boundaries of the scale. This type of unstructured scale is one with which most panelists feel readily at ease, in that it requires them only to give an immediate impression of a particular attribute in a product. Whether this scale should be used as though it were an equal-interval scale, requires further validation.

Magnitude estimation has been shown to work well in the analysis of a variety of sensory attributes in foods. The main doubt which has been cast upon its use, is whether or not a true ratio scale is produced. There seems no doubt that if this is so, then magnitude estimates are very valuable to the working technologist.

When sensory profiling techniques are used, the researcher seeks a sensory scale which has few inherent problems in its usage and provides data from which conclusions can be drawn with some assurance. For these reasons, the sensory scales used in the present study were compared not only for such factors as ease of use and the problems inherent in their usage but also for their effectiveness in discriminating between samples and in explaining variance in terms of experimental factors.

CHAPTER III

METHODS

1. INTRODUCTION

The first section of the methods describes sample processing and collection. Most of the whole milk powder samples evaluated in this project were commercially processed samples and general methods for processing these samples are described. Sampling procedures for the collection of the commercial samples are outlined, as are the handling procedures for samples once they had reached the New Zealand Dairy Research Institute.

Sensory evaluation of these powders was then carried out by the trained sensory panel. Methods for the preparation of samples, the serving of the samples and the testing environment used are detailed. A detailed discussion of the methods used to establish the sensory profile for whole milk powders is given in Chapter IV. A number of objective measurements were also carried out to characterize the whole milk powder samples. Reflectance measurements of colour using the Hunterlab D25 colorimeter are described, as are the estimations of total colour using a Bausch and Lomb Spectronic 20 spectrophotometer. Particle size distribution measurements, made to characterize the textural properties of whole milk powder are outlined. Viscosity measurements were made to characterize the reconstituted milks using both a capillary viscometer and a cone and plate viscometer.

2. SAMPLE PROCESSING AND COLLECTION

2.1 Background to Processing of Milk Powders

Drying milk to preserve it has been carried out for centuries. According to Marco Polo's accounts of his travels in Asia, Mongolians produced milk powder by drying the milk in the sun. Milk powder is produced today on a large scale in modern plants. In the drying process, water is removed from a liquid product (in this case milk) so that the product becomes solid. Spray drying is the principal method used for drying whole milk in New Zealand. In spray drying, the milk is first concentrated by evaporation under vacuum before being dried in a spray tower.

Milk is received and stored in large refrigerated silo tanks. Standardization of the milk is carried out to produce milk with a specified constant fat content. The milkfat is standardized in ratio to the solids-not-fat so the dry product will meet the standard of not less than 26% fat. This requires a fat content of 3.2%, assuming the solids-not-fat is 9-9.5%. Some milk is standardized to have 28% fat or higher in the dry form (Hall and Hedrick 1966).

The milk is then preheated before passing to the evaporator. Usually, tubular heat exchangers are used for preheating the milk. However, direct steam injection may be used for high heat powders. Preheating presents a paradox. Low-heat treatment minimizes the cooked flavour in milk powder, but does not develop anti-oxidants for delay of oxidation (one of the principal factors in keeping quality). Usually the primary consideration is given to prolonging the shelf life. Preheating also destroys the enzymes. If the lipase enzymes are not destroyed, hydrolytic rancidity will occur in the reconstituted milk. Preheating is also used to kill the viable micro-organisms in order to give a whole milk powder with a low total count. Preheat treatments typically used in New Zealand powder plants include: 95°C for 20s, 100°C for 5s and 110°C for 20s.

Following the preheat treatment, the milk passes to the evaporator where it is concentrated from about 13% solids to a final concentration of 43 to 50% solids. Evaporation takes place in multiple-effect evaporators. Evaporators in current use in New Zealand have a maximum of four effects, although evaporators overseas may have up to six or seven effects. In a mutiple-effect evaporator, the units operate at increasing vacuum in the direction of vapour movement through the units. The first effect temperature is normally limited to a maximum temperature of 70°C. Above this temperature there is a risk that the protein/salt mixture will precipitate on the tubes reducing heat transfer coefficients. At the lower temperatures of evaporation there is also less heat damage to the product. The product enters the top of the unit and is distributed evenly over the inside of the tubes which are heated with steam. Moisture removed moves downward to the vapour separator as does the concentrated product. The concentrate is then passed to a subsequent effect for further evaporation.

The concentrate is then homogenized at pressures of 5-10 MPa at 50 - 80°C. A homogenizer is used if the plant utilizes a centrifugal spinning disc for atomization. However, if pressure nozzles are used for atomization, homogenization is carried out through an homogenizing valve attached to the pump. The temperature of the concentrate may be boosted to 60 - 80°C in a heat exchanger prior to atomization. The concentrate is atomized inside the drying chamber. Atomization of the concentrate is carried out using either pressure nozzles or a centrifugal spinning disc. The purpose of atomization is to obtain many small particles with a large surface area which provide easy transfer of heat to and transfer of moisture away from the droplet (Hall and Hedrick 1966). A wide distribution is produced in the atomizer, from approximately 10μm to 150μm. Air for the drying is filtered and heated before it passes into the drying chamber and mixes with the atomized product. After the product is dried, the powder and air are separated. This most frequently takes place in a cyclone separator.

Drying of milk powder may be performed in two stages, spray drying to a moisture content of around 6% followed by secondary drying. This technique leads to greater thermal economy and plant capacity and produces a product with better properties, such as particle solubility. This technique has also been shown to lead to higher aroma retention (Kerkhof and Thijssen 1975). All whole milk powder produced in New Zealand is processed in two stage drying plants. Vibrating fluid bed driers are most commonly employed although pneumatic conveying driers may also be used for secondary drying. The powder is cooled in the last stage of the fluid bed by treatment with ambient or chilled air. It is then conveyed to storage bins and packing operations.

Agglomerated whole milk powder is produced by collecting the fines removed in the fluid bed and the spray drier chamber and returning these to the atomization zone of the drier for agglomeration with the atomized droplets of concentrate. If a cold water instant whole milk powder is being produced, a coating of lecithin is applied to the powder by spraying soybean lecithin on to the powder in the fluid bed.

2.2 Sample Collection and Reception

Samples of whole milk powder were collected throughout two dairying seasons from five commercial dairy factories. These represented some of the larger milk powder factories in the country and had a range of processing equipment in use. Of the five factories, one was situated in Northland, three in the Waikato region and one in Taranaki. Thus, samples received were produced from milk from different climatic conditions, processed on a variety of equipment. A record was kept of the processing conditions used for all powder samples.

Sampling is carried out by the dairy factories for the routine testing of whole milk powders by their own laboratories and by the Dairy Division of the Ministry of Agriculture and Fisheries. Factories are required to sample from every 180 bags of whole milk powder which come off the packing line (where the powder is packed directly) or at an equivalent rate. Samples were taken for this project at the same time as sampling was carried out for the factory laboratory. During the first season, a one kilogram sample of whole milk powder was taken once a week for evaluation in this project. The sample was packed into a foil-laminate sachet, heat-sealed and sent to the New Zealand Dairy Research Institute.

During the second dairying season, the frequency of sampling was increased to once every two days for the first and last ten weeks of the season. During the middle part of the season, powder sampling rates were reduced to once every fortnight. This permitted a close study of the beginning and end of season (where changes were greatest) to be undertaken. Powder samples were received at the New Zealand Dairy Research Institute, stored at ambient (22^{o}C) temperature and evaluated within 7-14 days of processing.

3. SENSORY MEASUREMENTS

3.1 Introduction

Sensory evaluation of the whole milk powder samples was carried out at the New Zealand Dairy Research Institute using the selected panel and sensory profile which had previously been established. During the first dairying season, a comparison of scaling methods for use with this sensory profile was carried out. Three sensory scales were in use: a 0-10 linear scale, a semi-structured linear scale with two anchor points and magnitude estimation scaling. The questionnaires for the three respective scaling methods are shown in Table 5 (p 75), Appendix 1 and Appendix 2. The scaling methods were assigned randomly amongst the three days of the week when sensory testing was carried out. The same powders were evaluated on each of these three days, the only difference being the scale used for evaluation.

During the second dairying season, only the 0-10 linear scale was in use. The questionnaire used during this season is shown in Table 6 (p 79). The work concentrated on evaluating more whole milk powders to clarify the differences established during the first dairying season.

3.2 Preparation of Samples for Sensory Evaluation

3.2.1 Principles of Sample Preparation for Sensory Evaluation

Samples should be prepared for sensory evaluation so as to standardize conditions and avoid flavour pick-up. Larmond (1977) stated that preliminary testing was usually necessary to determine the preparation method of a product. All the preparation factors should be predetermined and kept constant throughout tests on the product. The samples each panelist receives must be typical of the product. Panelists are influenced by irrelevant characteristics of the samples. Because of this, every effort should be made to make the samples from different treatments identical in all characteristics except the ones being judged.

3.2.2 Preparation of Powders for Colour Evaluation

For the sensory evaluation of colour, whole milk powder was taken from the foil/laminate sachet, pressed carefully into a 60mm x 10mm glass petri dish and levelled with a metal spatula. The lid was placed over the powder, taking care not to disturb the surface of the powder.

3.2.3 Preparation of Powders for Texture and Aroma Evaluation

Preparation of the powder samples for the evaluation of textural and aroma characteristics was carried out approximately 90 minutes before each sensory evaluation session. Powder samples were measured out into coded 50ml Kimax beakers using a 5ml plastic measure. A measure of powder was taken from the foil/laminate sachet, compressed and levelled carefully with a spatula. Each sample was poured into a beaker and covered with paraffin film to ensure the retention of aroma compounds.

3.2.4 Reconstitution of Milks for Aroma and Flavour Evaluation

The milk powder was reconstituted to a 12.5% (by weight) solution for evaluation by the sensory panel. Fifty grams of powder were weighed out and poured on to 350g hot (50^{o}C) water then mixed using a Jiffy milk-shake mixer (Autocrat Radio Ltd., Auckland, New Zealand) for 60 seconds. Each sample of reconstituted milk was then stored in a light-proof cupboard to protect it from the oxidative effects of fluorescent lighting. Samples were allowed to hydrate for 120 minutes before sensory evaluation took place.

Approximately 40 minutes before the session, the temperature of the reconstituted milk samples was checked and brought down to 24°C by placing the samples in ice water. Samples were poured into coded 50ml beakers, each sample being approximately 30ml. The beakers were then covered with paraffin film, again to retain the aroma of the sample.

3.3 Serving Procedures for Sensory Evaluation

3.3.1 Background to Serving Procedures

Samples should always be the same in form, consistency, colour and appearance. The amount of sample presented should be constant throughout the testing. Panelists should receive enough sample to taste back and forth until they can make a decision. Uniformity of temperature is generally agreed to be a necessary condition in the sensory testing of foods (Peryam and Swartz 1950). For most sensory tests, the samples are served at the temperature at which they are normally eaten. However, it is sometimes found that panelists are able to discriminate better when the samples are slightly warmer or slightly cooler than normal (Larmond 1977). Serving utensils should not impart any taste or odour to the product. Identical containers should be used for each sample so that no bias will be introduced from this source. Unless differences in colour are being masked, it is wise to use colourless or white containers (Larmond 1977).

3.3.2 Serving Procedures used in Present Project

The serving procedures for this project were determined by the panel during the training period. It was decided that the estimation of colour would be made by pressing the milk powder into 60mm x 10mm glass petri dishes and observing the colour of the powder through the glass lid of the petri dish. Evaluations of colour were made with the samples place on a white Seratone (New Zealand Forest Products Ltd, Auckland) liner, the panel having decided that this was a suitable background for these observations.

Both powders and reconstituted milk samples were served in small, clear beakers and covered with paraffin film in order to retain the aroma. The panel considered several materials as coverings for the beakers. The paraffin film was felt to give a convenient covering with no detectable taint being transferred to the sample.

The quantity of powder for serving was determined also. A volume of 5ml powder was considered an adequate quantity to observe powder characteristics and to evaluate the aroma of the powder. Similarly, a volume of 30ml reconstituted milk was decided upon, sufficient for aroma, flavour and textural evaluations in these samples. The temperature of serving was set at 22^{o}C (ambient room temperature). This temperature has been used at the Institute for several years for serving reconstituted milk powders. Although this was slightly cooler than the temperature at which these products might be consumed in tropical countries, no marked difference has been found in the ability of panelists to discriminate between samples at 22^{o}C and slightly higher temperatures, 30^{o}C for example.

Sensory evaluation sessions were held on Tuesday, Wednesday and Thursday of each week. All formal sessions were held mid-morning. Arrangements were made each day for ten panelists from the total pool of twenty to come to this session. A record was kept of panelists attending sessions, so that the burden of evaluations was spread evenly over the total panel.

For each session, a white liner was placed in a tray to act as a background for colour comparisons. Coded samples for colour, powder and reconstituted milk evaluations were placed on the tray together with the questionnaire. Panelists were supplied with water (22^{o}C) and a slice of white bread.

3.4 Testing Environment for Sensory Evaluation

3.4.1 Background to Testing Environment for Sensory Evaluation

Control of environmental factors is universally recognised as being of value in sensory work with food. Interruptions and distractions should be avoided during testing. Regularity, quietness, comfortable surroundings, orderliness, and smoothness of presentation of samples have all been emphasised (Amerine et al. 1965). For sensory evaluation a special testing area is used so that distractions can be minimized and conditions can be controlled. The testing area should be a quiet comfortable environment, if possible the room should be air-conditioned. Foreign odours and odours from other food preparations should be kept from the testing room.

For most types of testing, the panelists are required to make independent judgements. In order to eliminate distraction and prevent communication among the panelists, individual booths are used. The colour of the booths should not influence the appearance of the product being judged. An off-white or light grey colour is usually recommended. Lighting should be uniform and should not influence the appearance of the product to be tested.

3.4.2 Testing Environment used for Present Project

For this project, all formal sensory evaluation sessions were carried out in the sensory panel room of the New Zealand Dairy Research Institute (see Figure 1).

The panel room is adjacent to the Product Evaluation laboratory, where the preparation of the milk powder samples was carried out. The room is 5.49 metres long by 1.52 metres wide and 2.74 metres high. A grey laminex bench, 0.53 metres wide, runs the entire length of the wall adjacent to the Product Evaluation laboratory. Grey laminex partitions divide the bench into eight booths, each 0.61 metres wide. Grey laminex lines all three sides of each booth to a height 0.61 metres above the bench top. Each booth has a spittoon with running water and a cold water tap. A quarter-round transfer slide in each booth facilitates the passing of samples from the laboratory to the panel room. The room is lit with Philips incandescent luminaires, Catalogue No. DGN 840 (Philips Electrical Industries of New Zealand Ltd., Lighting Division, Auckland, New Zealand). Interchangeable red and white spotlights are available and all can be controlled by a dimmer switch. The room is air-conditioned and under slight positive pressure.

4. OBJECTIVE MEASUREMENTS

A number of objective measurements were made on the whole milk powder samples received throughout the two dairying seasons. Measurements were made to characterize colour and texture in both the powders and the reconstituted milks.

Figure 1. Photograph of the New Zealand Dairy Research Institute sensory panel room.

4.1 Colour Measurements

4.1.1 Background to Reflectance Measurements of Colour

Colour is an optical sensation, dependent on light. Visual perception by the observer is a result of how the eye interprets the light reaching it from objects. Colour is perceived and arranged into three-dimensional configurations. Hue, saturation and brightness together are used to describe the three dimensions of a colour as a total visual experience (Burnham et al. 1954).

To be useful, visual evaluations of product appearance must be precise and reproducible. This requires that the method and physical arrangement of observation be the same for all evaluations. Representative samples should be prepared for measurement in exactly the same way and should be presented to the instrument in a standard, repeatable manner (Hunter 1975).

A number of different instruments have been used to measure colour in milk and milk products. In the food industry, it is more common to measure the colour of samples by means of tristimulus colorimetry rather than by spectrophotometry (Francis and Clydesdale 1975). There are many different types of colorimeters which are in use today. Langsrud and Solberg (1976) used a Photovolt 670 reflectance meter to measure colour changes in dairy products.

Francis and Clysdesdale (1975) believed that dehydrated products could probably be measured adequately by tristimulus colorimetry on the loose powder. More accurate colour data could probably be obtained by pressing the milk powder into a disc. Hunter (1975) suggested that powders should be poured into a container with a transparent window in the bottom. The sample must be compacted to a uniform depth and measurements made through the bottom window. Bosset and Blanc (1978) confirmed this when they studied the suitability of tristimulus colorimetry for the analysis of colour in milk and milk products. These workers used a Hunterlab D25 D-2 colorimeter equipped with an 'A' measuring head. The Hunterlab D25 colorimeter is a four-filter instrument using solid state electronics with an *L, a, b,* colour scale readout. The *L, a, b,* colour scale has the advantage of giving a closer approximation to visual judgement than other colour scales. Bosset and Blanc (1978) considered this instrument useful for precise colour measurements of milk and milk powder products, the accuracy and reliability of the readings being very good.

4.1.2 Method for Reflectance Measurements of Colour

A Hunterlab D25 P-2 Colorimeter (Hunterlab Associates Laboratory Inc., Fairfac, Virginia, USA) was used for reflectance measurements of colour in whole milk powder samples. Before use, the instrument was calibrated. The calibration procedure consisted of two parts; standardization on a white tile (to calibrate the top of the scale) and zero adjustment on black glass (to calibrate the bottom of the scale).

Powder samples were presented for measurements in a similar fashion to that used for the sensory panels. Whole milk powder was compacted carefully and evenly into a 60mm x 10mm glass petri dish and levelled with a small metal spatula. The lid was placed on the petri dish and the dish placed with its base on the reflectance port. Measurements were taken for the *L* (brightness), *a* (blue-yellow colour component) and *b* (red-green colour component) values. In addition, measurements were made on all samples for the Yellowness Index (YI), a calculated value described by Hunter (1975) which is useful in measuring variation in the yellowness of products. Reflectance measurements were made on all powders using a white background. A 200mm x 200mm square of white Seratone board was used as the white background. This material had been used as the background for sensory assessments of colour.

4.1.3 Background to Spectrophotometric Measurements of Colour

Nelson (1948) showed that the colour of heated milk could be measured spectrophotometrically but liquid systems were subject to error due to particle size and other components that influence the degree of scattering. Spectrophotometric methods were limited in their usefulness as they were related only indirectly to the consumer's perception of colour in a foodstuff.

Buma et al. (1977) studied seasonal changes in milk using a Unicam SP500 spectrophotometer. They found that major colour changes took place when the cows were transferred on to or off pasture. Measurements made at 460nm and 550nm were found to give the largest colour differences for samples. These workers concluded that the colour of milk varies considerably during the year. They attributed the colour variation of milk to the variation in the colour of the milkfat. The main component in the milkfat which was thought responsible for this variation in selective light absorption throughout the year was the β-carotene content. These workers found the spectrophotometric readings at 460nm were strongly related to the β-carotene content of the milkfat.

Seasonal variation in the colour of New Zealand milkfat has been studied by a number of workers (Barnicoat 1947, McGillivray 1952, McDowell 1956, McGillivray 1956, Norris et al. 1971, Keen and Udy 1980). Barnicoat (1947) carried out the first estimations of carotene in New Zealand milkfat using a B.D.H. Lovibond Tintometer. The non-saponifiable fraction of the milkfat was diluted with chloroform to make these estimations. A later worker, McGillivray (1952), dissolved the milkfat in petroleum ether and made the carotene estimations with a Beckman Model D.V. Photoelectric spectrophotometer at 450nm. Norris et al. (1971) used a similar method, dissolving 2g milkfat in 25ml petroleum ether and taking readings at 450nm.

4.1.4 Method for Spectrophotometric Measurements of Colour

To determine the total colour (calculated as β-carotene) of whole milk powders, the milkfat was first extracted from the powder. A modification of a method described by Newstead and Headifen (1981) for the estimation of peroxide values in whole milk powders was used for this extraction.

A 10g sample of whole milk powder was weighed out into a 50 ml pyrex beaker and 20ml hot (50°C) distilled water added to it. The mixture was stirred and the sample allowed to hydrate for 60 minutes. The reconstituted sample was transferred to a 150mm x 25mm diameter glass-stoppered test-tube and stood in a water bath at 70°C for 3 minutes. Fifteen millilitres of de-emulsification reagent was then added to the sample. This de-emulsification reagent consisted of 50g sodium citrate, 50g sodium salicylate and 86ml n-butanol made up to 450ml with distilled water. The hydrated sample and de-emulsification reagent were shaken vigorously and stood in the water bath (70°C) for a further 5 minutes. The mixture was then transferred to a Babcock cream bottle, stood in the 70°C water bath for 1 minute and centrifuged at 1000 rpm and 190mm radius for 3 minutes at 60°C, as for the Babcock fat determination (A.O.A.C. 1975). Hot (60°C) distilled water was added to bring the fat into the neck of the bottle. The bottle was then centrifuged for a further 2 minutes and left standing in a water bath at 70°C until the fat had cleared. Duplicate extractions were carried out on each sample of whole milk powder.

Once the fat had cleared, 1.15ml liquid milkfat were pipetted into petroleum ether and made up to 12.5ml. This volume of milkfat was the equivalent of 1.0g milkfat (calculating the density of milkfat as approximately 0.9) as used by Norris et al. (1971). The total colour of the milkfat (calculated as β-carotene) was estimated using a Bausch and Lomb Spectronic 20 (Bausch and Lomb Corporation, Rochester, New York USA). The spectrophotometer was calibrated with a petroleum ether blank. Readings were made on each sample at 450nm, as suggested by Norris et al. (1971). The total colour of the milkfat was calculated as micrograms β-carotene per gram of milkfat. Using the chemical analyses of the milk powder samples, total colour was also calculated as micrograms β-carotene per gram of powder.

4.2 Particle Size Distribution Measurements

4.2.1 Background to Particle Size Distribution Measurements

Baldwin (1977) believed that the appearance of milk powder, on opening a consumer pack, is an important characteristic and should be given consideration in the manufacture of powder for domestic consumption. In an attempt to determine the major factors affecting the appearance of whole milk powder, this worker made a survey of powders available in a number of different overseas markets. Powders were scored on a 0-5 scale for appearance where a powder rating 0 was granular while a sample rated 5 was cohesive and caked. The appearance score was found to correlate most strongly with the particle size of the powder and in particular with the maximum particle size. Baldwin (1977) believed that this property of the powder is probably related to the limit of resolution of the human eye which is approximately 0.2mm.

4.2.2 Method for Particle Size Distribution Measurements

The method used in this project for the determination of particle size distribution in whole milk powders was based on a procedure devised at the New Zealand Dairy Research Institute and described by Baldwin and Sanderson (1973). The percentage of weight of powder falling into different size classes was determined by sieving on standard sieves. The incorporation of a free-flow agent enables this sieve analysis method to be applied to fine powders, such as whole milk powder.

The ambient humidity was first checked to see that it was less than 70% R.H. (tests were not carried out above this figure because of moisture uptake by the powders). A set of 200mm D sieves together with pan and lid to NZSS 196 (1963) was chosen, suitable for the powder type under consideration. For agglomerated powders a set of sieves was used with following aperture sizes: 500 microns, 250 microns, 125 microns, 90 microns and 63 microns. For non-agglomerated powders a set of sieves was used with aperture sizes of: 180 microns, 125 micron, 90 microns, 63 microns and 45 microns. The sieves were checked to ensure that there were no holes or slits at the edges.

Twenty five grams of whole milk powder were weighed out on to the finest sieve of the set and pan, together with 0.25g Syloid 74 free-flow agent (W.R. Grace Co., Davidson Chemical Division, Baltimore, Maryland). The two powders were mixed gently and then sieved on the finest sieve for 5 minutes. The oversize powder from this step was then transferred to the complete sieve stack and sieved for 30 minutes. This step was carried out to prevent the blocking of coarser sieves by very fine powder. Two sieve shakers were used for these measurements, an Inclyno sieve shaker (Pascall Engineering Co. Ltd., Gatwick Rd., Crawley, Sussex) and an Endecott sieve shaker (Endecotts Ltd., Lombard Road, Morden Factory Estate, London).

The amount of powder on each sieve and in the pan was then determined. The top sieve was removed gently from the stack and any material adhering to the bottom side of the sieve brushed into the sieve below. The inclined sieve was then tapped gently, gathering the powder on one side and tipped out on to the balance pan. Any powder remaining was then brushed out. The sieve was then struck firmly and any material dislodged was brushed out also. This procedure was repeated with succeeding sieves. Weighing was carried out reasonably quickly to minimize moisture uptake in the powders. From these measurements, the percentage on each sieve was calculated as well as the cumulative percentage weight undersize.

4.3 Viscosity Measurements

4.3.1 Background to Viscosity Measurements

In mathematical terms, viscosity is defined as the ratio of shear stress to shear rate. Foods exhibit a wide range of viscosities. At the low end are aqueous solutions which behave as Newtonian fluids, their viscosity being independent of shear rate. As viscosity increases the systems become increasingly non-Newtonian. Milk is an emulsion of fat in an aqueous medium with proteins dispersed colloidally. The viscosity of milk relates closely to the sensory term 'thickness' (Sone 1972). Homogenized whole milk seems to behave essentially as a Newtonian fluid in spite of the presence of two distinct phases. However, viscosity measurements of whole milk are complicated by the separation of cream.

Capillary viscometers may be used for viscosity measurements of Newtonian fluids, such as homogenized milk. The liquid is made to flow through a capillary tube under the influence of a known pressure difference. The rate of flow is measured by determining the time required for a given volume to pass a graduation mark. Capillary viscometers measure the rate of flow through a capillary tube, utilizing Poiseuille's law which governs the laminar flow of liquids through capillaries.

There are a few limitations in the use of capillary viscometers. Firstly, there is some difficulty in obtaining satisfactory precision in the instrument. Even slight variations in the capillary tube will affect the rate of flow through the tube. For accurate results it has also been recommended that both the viscometer and the liquids be placed in a constant temperature bath.

Rotational viscometers of the cone and plate type are useful in viscosity measurements also, being particularly suitable for non-Newtonian fluids. In cone and plate viscometers, the fluid is sheared in a small gap between a rotating cone and a flat plate. When the design is such that the apex of the cone just touches the surface of the plate, the shear rate is uniform throughout the entire fluid sample.

With a cone and plate viscometer, only a small sample is required and temperature control is relatively good. Shear rate is directly proportional to the rotational speed of the cone and shear stress to the torque exerted on the spring. A high shear rate can be achieved, the shear is variable and it is possible to make flow curve recordings to gain a more comprehensive idea of a sample's rheological properties (Towler and Cooper 1979).

4.3.2 Viscosity Measurements using Capillary Viscometer

A Cannon-Manning Semi-Micro viscometer size 75 Catalogue No. CMSMC (Cannon Instrument Co., State College, Pennsylvania, U.S.A.) was used for the determination of viscosity in the reconstituted milks. This instrument is suitable for the measurement of viscosities of small liquid samples requiring a charge of only 1.0 ml. Viscosity measurements were made on reconstituted milk samples prepared for the sensory panel. To carry out these measurements, the Tamson Constant Temperature water bath Type TCV 40 (P.M. Tamson BV, Zoetermeer, Holland) was adjusted to 22°C. The capillary viscometer was placed in a holder and inserted into the water bath, then carefully aligned vertically.

One millilitre of reconstituted milk was pipetted into the left hand arm of the viscometer. The sample of milk was pipetted from the middle of the container, to avoid the possible inclusion of fat globules from the surface or sediment from the bottom. Using a rubber bulb, the sample was sucked gently through into the right hand arm of the viscometer to the crosspiece above the mark on the bulb. The sample was allowed to come to water bath temperature (approximately five minutes).

Again, the rubber bulb was used to suck the sample through to the crosspiece above the upper mark of the bulb. To measure the efflux time, the liquid sample was allowed to flow freely down past the upper mark on the bulb to the lower mark and the time for this to occur was noted using a stop-watch. Measurements were repeated until two readings were obtained within 0.4 second of each other. In warm weather, it was found necessary to add a small quantity of ice to the water as each reading was made in order to keep the water bath temperature constant. The capillary viscometer was then cleaned thoroughly, first with a detergent solution then with distilled water and finally rinsed with Analar grade acetone. The viscometer was then dried ready for re-use. The viscosity of each sample was calculated by multiplying the efflux time (in seconds) by the viscometer constant.

4.3.3 Viscosity Measurements using Cone and Plate Viscometer

A Ferranti-Shirley cone and plate viscometer (Ferranti Ltd., Boston, Manchester, England) was used to examine the flow behaviour of reconstituted milk powders in this project. Although reconstituted milk powders appear to be Newtonian, the effect of increasing shear rate upon these liquids was of considerable interest, especially when compared with the sensory panel's perception of 'thickness' in the same samples.

The Ferranti-Shirely viscometer consists of a thermostatically controlled plate on which a small quantity of the sample liquid (sufficient to fill the space between plate and cone) is placed and an inverted cone with an apex angle of nearly 180°. The plate is raised until it is within 0.025 mm of the apex of the cone. For taking measurements, the cone is rotated at any desired speed up to 1000 rpm and the viscous drag is measured electronically. All parts of the sample are sheared at the same shear rate. Measurements can be made at a much higher shear rate than attainable with most other viscometers (Towler 1971).

The water bath was turned on and adjusted to 22°C. The viscometer was calibrated according to the maker's instructions. The Extra Large cone was used for these measurements. The plate with the capstan was then lowered and a small quantity of reconstituted milk powder pipetted on to the centre of the plate. With cone speed still at 5 rpm, the plate was raised. The scale factor control was set at xl, the speed at $500s^{-1}$ (the first speed required) and a reading taken off the indicator unit. Readings were taken at the equivalent of $500s^{-1}$, $1000s^{-1}$, $1500s^{-1}$, $2000s^{-1}$, $2500s^{-1}$, $5000s^{-1}$, $10000s^{-1}$, $15000s^{-1}$, and $18000s^{-1}$. The cone and plate were cleaned with tissues and water, then dried thoroughly before the next set of readings was made.

CHAPTER IV

GENERATION OF A SENSORY PROFILE FOR NEW ZEALAND WHOLE MILK POWDERS

1. INTRODUCTION

This chapter describes the work carried out to fulfil the first aim of this project, which was to establish a sensory profile for New Zealand whole milk powders. Before any evaluations could be made of possible variation in these whole milk powders, the sensory properties of the product needed to be described and a sensory profile established.

To establish the sensory profile, it was first necessary to study the literature regarding the sensory properties of whole milk powder. Therefore, the first part of this chapter contains a brief survey of the pertinent literature. Having surveyed important aspects of the sensory properties, it was then possible to establish the sensory profile.

This profile was established in a systematic fashion using discussion sessions with a group of panelists selected for the project. The second part of this chapter details the steps taken in the selection of the panel, the criteria used for this selection process and the various steps taken in establishing the sensory profile. These include the organisation of the group discussions and a detailed description of the stages through which the panel progressed as they established a sensory profile for New Zealand whole milk powders.

2. SENSORY PROPERTIES OF WHOLE MILK POWDER

Many sensory properties are evaluated by the consumer as he or she assesses a milk powder. All these properties contribute to the consumer's evaluation of the quality of the product. These widely differing sensory properties can be divided into four main areas of study. These are the colour, aroma, flavour and texture of whole milk powders, both as a powder and as reconstituted milks.

2.1 Colour

The colour of processed milk, particularly dehydrated products, is of major concern to the industry but has come under relatively little consideration until recently. Baldwin (1977) believed that this sensory property of whole milk powder was an important characteristic and should be given careful consideration, particularly in the manufacture of powder for domestic consumption. The colour of whole milk powders is of concern since dark-coloured products may be considered old, or of inferior quality.

The heat treatment of milk, as occurs during the production of whole milk powder, has been found to affect the colour. Langsrud and Solberg (1976) found that in the systematic heat treatment of homogenized, pasteurized whole milk at 100^{o}C and 115^{o}C for different holding times, the products became white during the first part of the heat treatment. Later the whiteness decreased because of early browning, this browning reaction being fastest at the highest temperature. The yellowness of the milk remained constant during the first part of the heat treatment at 100^{o}C, while at 115^{o}C and 130^{o}C the yellowness started to increase at once. In addition, the dominating colour of the milk changed from green at the start of the heat treatment to yellow-red at the end.

The browning of milk powder during prolonged storage has been studied extensively. Reactions between lactose and milk proteins are responsible for these colour changes (Buma et al. 1977). However, very little browning occurs if the products are not subjected to severe heat treatment during drying or products are stored at 50°F (5^{o}C) or lower (Francis and Clydesdale 1975). These non-enzymatic browning reactions in dried milk powders occur as a function of accumulated heat treatment during processing and the temperature of storage. Tran and Gianone (1975) found that the greatest changes occurred in milk powder samples stored at high temperature (30^{o}C) and high (80%) relative humidity.

Buma et al. (1977) when they studied seasonal changes in milk found that major colour changes took place when the cows were transferred on to or off pasture. These workers concluded that the colour of the milk varies considerably during the year. They attributed the colour variation of milk to the variation in the colour of the milkfat. The main component in the milkfat which was thought responsible for this variation in selective light absorption throughout the year, was the β-carotene content. Differences as small as 1.5% in the percentage reflectance of the milk could be detected visually if judged simultaneously. Buma et al. (1977) believed that not only did the colour of fresh milk but also that of its products, such as whole milk powder, vary with the season. Milk products processed during the early part of the spring showed considerable colour differences from those produced later in the season.

2.2 Aroma

The aroma of a product, such as milk powder, is the sensory response evoked by volatile compounds in the powder or in the reconstituted milk. Characterization of the aroma or odour has been one of man's activities from his earliest existence, used as an indication to him of the freshness and wholesomeness of a foodstuff (Land 1975). The aroma of milk powders is imparted by a large number of compounds, the majority of which are very volatile. Upon drying, some of these volatiles may be lost, causing a decrease in aroma strength and a change in the overall impression of the aroma constituents. In drying processes, the removal of water and the loss of aroma are generally controlled by molecular diffusion inside the foodstuff. Under optimum conditions, it has been found that aroma constituents can largely be retained (Kerkhof and Thijssen 1975).

There has been little study made of the aroma characteristics of milk and milk powder, despite the fact that this characteristic is one of the first to be evaluated by the consumer in the powder and then in the reconstituted milk. One of the few studies made on these volatile characteristics was by Jaddou et al. (1978) on the flavour volatiles of heat-treated milks. These workers found that none of the non-sulphur compounds were present at concentrations exceeding threshold in any of the milks. Only hydrogen and methyl sulphides were present at concentrations above threshold. The decrease in concentration of each of the sulphur compounds during storage paralleled the decrease in intensity of a 'cabbagey' note to the extent that they appeared to be linearly related. A good correlation was also observed between the total volatile sulphur/ml milk and intensity of 'cabbagey' flavours. It was thought possible that all volatile sulphur compounds contributed to this particular flavour note.

Palo (1973) has described a method for the sensory evaluation of different aroma components of dairy products in parallel with the use of a gas liquid chromatograph

(GLC). A GLC was used with a double fractionation column enabling simultaneous parallel examination by fraction intensity detector and by olfactory assessment. While such a method offers a means of simlutaneous examination of the milk product, this gives no real indication of aroma changes as they are related to the other sensory properties of dried milk products. In addition, it is likely that seasonal changes will affect this sensory property, yet little work has been carried out in this area.

2.3 Flavour

There have been many studies published on the flavour of whole milk powders. These have included studies using highly sophisticated techniques for isolating aromatic compounds associated with various flavours and taints, as well as sensory evaluation techniques. Interest in the flavour of milk powders has centred around storage trials and little work has been done on the processing or seasonal changes in the flavour.

The flavour of fresh fluid milk is difficult to describe because it is a rather bland product. Milk may either have a slight sweet character as a result of its lactose content, or a slightly salty character as a result of chloride salts (Parks 1967). It is not definitely known what compounds contribute to the characteristic flavour of milk. Low molecular weight compounds present in trace amounts, such as acetone, acetaldehyde, butyric acid, and certain other low molecular weight fatty acids, have been suggested as contributing to flavour. Methyl sulphide imparts a flavour highly characteristic of fresh milk. Other low molecular weight compounds identified in fresh milk include formaldehyde, butan-2-one, pentan-2-one, hexan-2-one and heptan-2-one. Most flavours in dairy products cannot be attributed to one compound but rather to a mixture of compounds. Whereas one compound will show different flavour characteristics at various concentrations, mixtures of compounds may well accentuate this. Significantly, compounds which have been implicated in the characteristic flavour of milk have also been observed in higher concentrations in many of the more objectionable flavours which arise in milk. For example, methyl sulphide at concentrations above threshold, imparts a 'cowy' flavour to milk, a flavour which has also been associated with concentrations of ketones.

Whole milk powder has often been criticised for its flavour. The flavour of the freshest powder has been inclined to be highly 'cooked' with 'butterscotch' or 'cooked fat' overtones and deterioration during storage has resulted in flavour characterized as 'oxidised', 'tallowy', 'rancid', 'stale', 'fruity', 'coconut', 'malty', etc. (Mook and Williams 1966).

Shipe et al. (1978) sought a means of practical classification for the flavours found in milk and milk products. These workers decided that a classification based on the causes of particular flavours was the simplest and most useful. Their classification was made as an aid in training personnel to identify types of flavours and their causes at the same time. This type of classification eliminated arguments over whether an oxidised sample tasted 'metallic' or 'papery', bearing in mind that different panelists may perceive flavours differently. This type of 'causative' classification of flavours has been adopted for the present literature review.

2.3.1. Cooked flavours

A loss of volatile compounds is thought to be a contributing factor to cooked flavours in milk products, as is the formation of heat-generated flavour constituents. The development of 'cooked' flavour in milk powders is a function of the temperature and duration of heating. The flavour is thought to be the result of volatile sulphides, hydrogen sulphide in particular, which are liberated from the activated sulphydryl groups of β-lactoglobulin and to a lesser extent the proteins of the fat globule membrane. As the heat treatment is prolonged or increased to higher temperatures, the 'cooked' flavour gives way to a 'caramelised' flavour and the initiation of Maillard type reactions takes place. The particular compounds that contribute to this flavour note are not well defined.

Shipe et al. (1978) defined several kinds of heat induced flavours which occur in milk powder. These workers believed that hydrogen sulphide contributed significantly to cooked flavour but that other 'volatile sulphides' were also significant contributors. The 'cooked' or sulphurous note in milk powders dissipates upon storage and may not be noticeable after two or three days. A 'rich' or heated note is noticeable in milk exposed to high heat treatment, once the sulphurous note dissipates. It is not clear which compounds are responsible for this flavour but indications are that heat-induced diacetyl contributes to it. Other potential contributors include lactones, methyl ketones, maltol, vanillin, benzaldehyde and acetophenone. A 'caramelised' note has also been distinguished although it is not known whether this flavour differs from or is an extension of the heated rich note. Non-enzymatic browning has been suggested as a cause of this flavour note. There is also a scorched flavour which occurs in milk powders subjected to abnormally high temperature processing.

2.3.2 Feedy flavours

Flavours absorbed into the milk from cattle feed are generally recognised as causing taints in the milk and the resulting milk powder. The role of feeds in the flavour of milk does not follow a standard pattern. Certain feeds and weeds consumed by dairy cows have long been recognised for contribution to the appearance of abnormal and undesirable flavours in milk and its products. Onions, fermented silage, alfalfa, cabbage, turnips, rape, beet tops, musty hay etc. impart objectionable flavours to milk, but these can usually be avoided by controlled feeding practices. Many varieties of weeds when ingested by cows impart taints to milk and in some cases only minimal consumption of a weed is required to produce a strong flavour. The incidence of these weed taints in milk can be greatly reduced by good pasture management.

Flavours imparted to milk are not necessarily of the same characteristic as the flavour of the consumed feed. A particularly offensive flavour may become evident in milk following the ingestions of a plant which has inoffensive odour and flavour characteristics. The level of many of these flavours can be greatly reduced in milk and cream by vacuum steam distillation (vacreation). However, some weed taints, such as that produced by land cress, are intensified by heat treatment and cannot be eliminated from milk and cream by conventional vacuum pasteurization techniques (Walker and Gray 1970).

Products with a cress taint have traditionally been downgraded but there have been few, if any, complaints from overseas customers. Customers have sometimes described milk with this type of feed flavour as having a 'richer' flavour. Modler et al. (1977) showed that while consumers rejected a pronounced feed flavour in milk, they were unable to detect slight feed flavours. There was some evidence that feed flavour influenced the consumer's perception of product consistency, there being a greater tendency to categorize the product as 'heavier', 'richer' and possible 'sour' tasting (Modler et al. 1977).

2.3.3. Oxidised flavours

Whole milk powder has come under a lot of study because the off-flavour development in this powder is very different and much more intense than in skim milk powder. It has been concluded that the fat phase is either directly or indirectly accountable for the differences in the keeping quality of these powders (Mook and Williams 1966). Off-flavour development in whole milk powder associated with the fat phase has been shown to be due mainly to the chemical rearrangement of certain fatty acids as a result of heat and moisture, independent of oxygen, and to the production of carbonyl compounds as a result of oxidation of fat and fatty materials.

'Stale-fat', 'waxy' and 'oxidised' type flavours have been shown to be connected with methyl ketones produced by the action of heat, in the presence of moisture, on beta-keto hydroxy-acids and their esters. Lactones and methyl ketones are formed by heat treatment independent of oxygen, although oxygen could possibly play a part in forming their precursors (Mook and Williams 1966). Oxidised off-flavours associated with milkfat deterioration have been shown to depend upon the concentration and kinds of carbonyl compounds present. However, Boon et al. (1976) found that they were not able to simulate completely the typical 'cardboard', 'tallowy' flavour of an oxidised milk powder by incorporating synthetic mixtures of the identified monocarbonyls into homogenized milk. The taste panel considered the milk containing all the identified monocarbonyls to be similar but slightly more 'painty' than 'fruity' than the milk prepared from an oxidised powder. However, this milk was considered to be closer to the naturally oxidised milk than when individual monocarbonyls were added to fresh milk. Saturated aldehydes alone imparted a flavour to milk described by the panel as 'tallowy', 'stale' and 'musty'. When unsaturated aldehydes were included, flavour descriptions, such as 'tallowy', 'cardboard', 'painty' and 'fruity' were obtained. These workers believed that the overall flavour of an oxidised powder was further modified in the presence of unidentified carbonyl compounds and non-carbonyl compounds such as acids, alcohols or lactones.

The role of saturated and unsaturated aldehydes in promoting 'tallowy', 'painty', 'cardboard' and 'fishy' flavours in oxidised dairy products is well-established (Walker 1973). These oxidation processes continue under the influence of time, light, temperature and moisture. Oxidised flavours also occur in irradiated milk. The effect of light on milk in producing off-flavour has long been established (Hendrickx and de Moor 1969). Milk powders produced from light irradiated milk have been found to have a strong off-flavour. The colour of the milk powder changes also, probably as a result of the destruction of the riboflavin.

2.3.4. Non-oxidised flavours

These flavours which occur typically in the absence of oxygen, are often found in milk powders which have been gas-packed into consumer packs directly from the drying line. These 'fruity' and 'coconut' flavours have been found to result from the chemical rearrangement of hydroxy fatty acids by heat treatment to form lactones.

Lactones are produced by heat in the presence of water and the concentration is apparently correlated with the amount of heat applied during processing. Lactones are present in all heated milk and milk products but several of these are present in such low concentrations that they have very little or no significant effect on the flavour. The importance of lactone flavours increases during storage of milk powder as hydrolysis of the triglycerides progresses. The potential for lactone formation in milk is dependent on common variables such as feed, season, breed, stage of lactation and metabolic disturbances (Eriksen 1976). The most important lactones in the formation of these flavours are delta-decalactone, which is responsible for the 'coconut' flavour and delta-dodecalactone, responsible for 'peachy' or 'fruity' flavour (Mook and Williams 1966).

2.3.5. Seasonal Variation in flavour

Steen (1978) is one of the few workers who has made an investigation of seasonal variation in the composition of milk powders and its influence on the keeping quality of such powders. This worker tested freshly produced dried whole milk powders over a period of one year immediately after production and then after twelve, eighteen and twenty four months. The reconstituted milk was graded for its sensory properties on a 0-15 numerical scale. A tendency was found towards lower grades in the spring months and a slight decrease in the quality of the powder during storage. A pronounced fall in the quality of the powder was found to occur on storage at high humidity. Although this worker has added greatly to our knowledge of the effects of seasonal variation on the composition of whole milk powder, there was little attempt to correlate this information with variations in the flavour of whole milk powder or its other sensory properties.

2.4 Texture

Whole milk powder sold in overseas markets is stored for a period at the factory and either packed into consumer packs prior to shipping or shipped for repacking in the market place. It must then satisfy the consumer on the counts of appearance, dispersibility and flavour. Particular emphasis has therefore been placed on identifying the processing conditions which affect the subsequent quality of the powder (Lascelles et al. 1976). The free-flowing properties of milk powder are a very important physical property for the milk powder industry as it affects the storage, conveyance and packing of the powder (Hayashi et al. 1974). A free-flowing powder is very desirable and may be necessary if the powder is being dispensed for use in coffee or tea.

In an attempt to determine the major factors affecting the textural appearance of whole milk powder, Baldwin (1977) made a survey of whole milk powder samples available on a number of overseas markets. It was found that in powders with the best appearance, individual particles were visible giving a desirable granular appearance to the product. This worker concluded that the production of a powder of good appearance requires a powder with large particles to impart a granular free-flowing appearance. Conversely the presence of small particles will result in the formation of lumps on storage (Baldwin 1977). Since the consumer makes his or her first assessment on the powder quality according to the textural appearance and flow properties of the powder, it is important to consider both sensory and objective measurements of these qualities.

The consistency of reconstituted milk powder relates closely to the sensory term 'thickness'. Reconstituted milk powder can be considered as an emulsion of fat in an aqueous medium in which proteins are colloidally dispersed (Sone 1972). Normal milk contains about 8% particulate matter. Less than half of this consists of fat globules ranging in diameter from less than one micron to about eight microns and the rest is of colloidal dimensions (smaller than about 100 microns) and of micellar form. Milk also contains some fairly large molecules the so-called whey proteins (lactalbumin and lactoglobulins) and other soluble matter making a total of over 12% solids.

The chemical composition of milk is influenced by the growing conditions of each individual cow i.e. climate and feed, and this may produce differences in consistency. Cox (1952) believed that with such a complex product as whole milk, it was not to be expected that an observed physical property would behave accurately according to a simple fundamental law. Although some of the individual constituents affecting the thickness or viscosity of milk may have comparatively simple viscosity-temperature relations, it was not likely that these would combine in such a way that the resulting relationship was correspondingly simple. In fact, the viscosity observed on any occasion might be regarded as 'effective' or 'equivalent' viscosity depending on the particular circumstances and instrumental parameters e.g. instrument, shear rate etc. (Cox 1952).

Several workers have measured viscosity in milk and obtained many values. Cox (1952) attributed most of the discrepancies to differences in experimental conditions and underestimation of the fact that milk from widely varied sources and with different compositons might be expected to have different properties. Caffyn (1951) showed that milk was not quite Newtonian in behaviour, since measured viscosity decreased slightly on repeated shearing at temperatures below 60°C and rose slightly at temperatures above 60°C.

These effects were attributed to changes in the milk proteins. Raw milk, on the other hand, shows rather different characteristics. Its viscosity is independent of shear rate at temperatures in excess of 40°C but as the temperature decreases it becomes shear dependent (i.e. non-Newtonian) to an increasing degree (Sherman 1977).

2.5 Summary

Colour, aroma, flavour and texture are all important sensory properties in whole milk powders. Where detailed studies of sensory properties have been made, they have been studied in isolation. No attempt has been made to characterize all the sensory properties and to make an integrated measurement of all of them. The colour of milk powder is one of the first sensory properties to influence consumer acceptance of the product, yet it has been largely ignored by the dairy industry. Tristimulus colorimetry gives the nearest approximation to colour as perceived by the consumer. Little study has been made of the aroma characteristics in whole milk powder, yet this characteristic is evaluated by the consumer first in the powder and then in the reconstituted milk. In contrast, the flavour of whole milk powder has been the subject of much study. Although many of these studies involved detailed analysis of small concentrations of organic compounds, the sensory assessment of the powders has often been rudimentary. There has been little attempt to characterize the flavour attributes of milk powder and to measure changes in these attributes. The textural characteristics of whole milk powder have not been fully explored by the studies reviewed here. Although some study has been made of flow properties in milk powders, these studies have seldom related to consumer perception of this property. Nor has there been much study of the rheological properties of reconstituted milk powders. The rheology of milk has been studied in some depth but that of reconstituted milk powder has not.

3. DESCRIPTIVE SENSORY METHODS

The different aspects of the sensory value of foods are strongly inter-related. Colour and appearance, flavour and texture are all equally important parameters for the acceptability of a food product. The value of one of these influences the qualitative assessment of the others (Wuhrmann 1977). During sensory evaluation, which is decisive for the acceptance of foods, the sensory attributes of foods are integrated in the brain to form an overall quality impression. These attributes are perceived individually by the senses and judged in the following order: appearance, aroma, flavour and texture.

In an effort to find ways to evaluate all these sensory attributes in foods, sensory workers have developed descriptive methods of sensory analysis. One of the first descriptive methods of sensory analysis to be widely used was the Flavour Profile method developed at the Arthur D. Little Laboratories. This was a descriptive method which took into consideration the total impressions of first the aroma and then the flavour of a product. The independently recognisable aroma and flavour factors were also considered according to type, intensity and order of perception (Sjostrom et al. 1957). This method of sensory evaluation was founded on the natural process of evaluating and comparing flavours by describing impressions - either as a whole or by individual characteristics (Caul 1957). The profile panel has proved to be a useful and effective tool in dealing with numerous complicated and difficult flavour and odour problems on which no published literature existed (Caul et al 1958).

In a similar fashion to the way in which the flavour profile method was developed, Szczesniak (1963) developed the texture profile method. It was not accepted for many years that, as in the case of flavour, texture is composed of a number of different parameters of notes. Szczesniak rejected the evaluation of texture as part of flavour on both theoretical and practical grounds. It was not acceptable on theoretical grounds because texture is primarily physical in natural whereas flavour is chemical in nature. Szczesniak (1975) believed that the flavour profile method did not provide for sufficient breadth and depth of texture characterization. In the texture profile method, the list of descriptive terms was compiled by the trained texture profile panel based on its evaluation of the product in question. The basic vocabulary was then expanded to include words denoting different intensities of a characteristic such as soft, firm and hard (Szczesniak 1963).

These methods required a disciplined analysis to be carried out without the expression of any preference or final judgement as to the quality of the product involved (Sjostrom et al. 1957). Descriptive or common language terms are used for the characteristic notes. These character notes are, in physical and chemical terms, very complex but are described in a way that the panel understands and is agreed on the meaning of the terms. From such an agreement on terms, a panel may work out a tentative profile of a product for use in future sessions. Once the sensory components are described the intensities are studied (Jellinek 1964).

Profile methods made it possible to describe the effect of small changes in the general composition and nature of a product. From a physical and chemical viewpoint, any food product is a complex system and sensory profile methods offered a method of analysing this system in descriptive terms. The degree of difference between samples could be indicated on the basis of the intensity of individual characteristics. Perceptible factors are called character notes and are defined in descriptive or associative terms. However, association with a definite chemical or reference material is attempted whenever possible (Caul et al 1958). In addition to giving one-word descriptions of the perceptible factors and their intensities, a tabular profile lists the perceptible factors in the order in which they are perceived. Differences in the timing of the notes are large enough to be sensed and the order of appearance of notes is also very important (Caul et al 1958).

In their descriptions of the Flavour Profile method, Cairncross and Sjostrom (1950) placed considerable emphasis on the selection of the panelists. Since this method was designed to encompass the sensory profiling of many products, the selection procedure was a generalised one. Individuals were required to taste four solutions, one each of the basic tastes and to identify each solution correctly. They were then asked to rank three concentrations of sugar solutions in increasing order of intensity. Next, they were asked to sniff twenty different compounds, and if not to identify them, at least to describe them. A 55% score on the odour test was generally required to qualify for the descriptive panel. Panelists who qualified on these discriminatory tests were then interviewed and selected on their interest in the project.

A selection programme demands the use of samples known to be different so that the choice of panelists can be based on two performance factors, the ability to discriminate differences in the specific attribute that is being studied, at the required level of sensitivity, and the ability to repeat this discrimination. Vaisey (1977) stressed the importance of carrying out selection tests using the kind of food that will be used in the experimental programme. In recent years, researchers have shown that a panelist's ability to discriminate between the four basic tastes does not necessarily indicate an ability to discriminate between particular foodstuffs. Because of this, selection tests are best done using the specific kinds of foods to be tested. The most common selection tests for sensitivity use the triangle test, with the degree of difference between a sample being adjusted so that initially about 80% correct judgements are given. Simple tests are used first, foll-owed by tests of increasing difficulty. Candidates can then be ranked on the basis of correct judgements given (Martin 1973). Zook and Wessmann (1977) described the use of this type of selection programme for descriptive sensory panels at the Quaker Oats Company. These authors suggested the screening of approximately three times the number of judges required for the sensory panel and the subsequent dropping of the bottom two-thirds of this group.

In their description of the flavour profile method, Caul et al. (1958) emphasised the importance of an orientation period of group discussions in preparation for formal profile panels. The general procedure involves meetings of the panel where the objectives of the project are out-lined. Samples of the test product are introduced and then studied by the panel. The optimum conditions for handling and presentation of samples, including temperature control, type of vessel and actual quantity to be placed in the mouth are determined during these group discussions. At the same time the language used to describe the various sensory attributes in the product is developed (Caul et al. 1958). The terminology used to describe the products comes from the panel members themselves. Zook and Wessmann (1977) stressed that all panel members must understand and feel comfortable with the descriptive terms to be able to use them effectively during formal profile sessions. Members of the groups must feel on an even footing so that all will make contributions to the general pool of knowledge about the sensory characteristics of the product.

In the organisation of discussion groups for sensory descriptive analysis, Zook and Wessmann (1977) emphasised the importance of the panel leader. The panel leader does not take part in the descriptions of the products. His or her role is to keep the group functioning, provide standards and training samples as needed, prepare trial score sheets from the terms suggested, think of ways to clarify confusion and test and monitor the judges. The job of the panel leader, requires not only normal sensory abilities but also understanding of people, patience and the ability to plan and execute flavour tests (Caul 1957).

Cairncross and Sjostrom (1950) in their description of the flavour profiling technique laid great emphasis on the character notes of a product. These were the identifiable aroma and flavour factors present in a food and were defined in descriptive or associative terms. Jellinek (1964) believed that it was easy to describe odour and flavour components but that it had to be realised that panel members are human beings. To list thirty or even more components did not make a good panel member. Fantasy could enter into analysis and make the results of no value. This worker felt that it was better for a panelist to list initially only two of the components about which he or she was absolutely certain than to include many question marks in an analysis. Daget (1974) suggested that to form the sensory profile of any product, terms should be selected by the panelists from a larger glossary of terms. This list should contain an adequate amount of information but should be restricted to essential features only. The characteristics to be discarded were those which were highly improbable or unachievable. Terms which did not provide any additional information in relation to the problem involved were also discarded. Jellinek (1964) emphasised the need to anchor odour and flavour descriptions by sensory standards. The earlier a direct comparison between test product and reference standards was undertaken, the earlier descriptions based on fantasy or childhood associations could be omitted.

4. GENERATION OF A SENSORY PROFILE FOR WHOLE MILK POWDER

In generating a sensory profile for whole milk powders, an attempt was made to describe all the sensory properties which might influence consumer acceptance or rejection of the product. Because there was no information as to which properties were important to the consumer, it was necessary to describe all possible sensory properties. By evaluating all the sensory properties, it was hoped that these sensory profiles could be related, at some later date, to requirements for a particular marketplace.

4.1 Selection of Sensory Profile Panel

Selection programmes are designed to choose sensitive panelists for a specific experimental project from a large group of candidates. Age, sex or smoking habits are not usually considered to be factors in the selection of panelists. The panelist does not have to like the test product, but Ellis (1966) considered that it is probably better if he or she does. Panelists should be interested in participating in the sensory project as motivation is important to the performance of the panel, especially in long term panels. Panelists should also be readily available for sensory testing when needed, persons who have occupations which take them to other locations are not generally considered suitable.

The sensory panel for this project was selected from staff members of the New Zealand Dairy Research Institute. It was decided that a relatively large panel of some twenty members would be selected for training. This number was chosen because of the length of the project and consequent fatigue of a small panel and also because of the mobility of Institute staff members. Almost all staff members travel throughout the country working with the dairy industry, especially during the dairying season (the busiest time for this project). Because of staff changes at the Institute, it was necessary to select seven new panel members before the second dairying season began. These panelists went through the same selection and training programme which had been used for the initial panel.

Prospective panelists were initally screened to check for colour blindness, since colour was one of the properties to be evaluated. Then some sixty members of the Institute staff were screened for the ability to discriminate between reconstituted milk powders. It was felt that the ability to discriminate between whole milk powders by flavour was the most important factor in selecting the panel. Consequently, a number of whole milk powders with known flavour differences were used for the screening programme. Because of the nature of whole milk powder, it was possible to make the flavour differences between samples progressively smaller by use of dilution techniques.

Panelists were required to evaluate some fourteen to sixteen triangles of whole milk powder, two triangle tests being administered at each session. Several of the triangle tests were reversed although these reverse triangles were administered at different sessions, to prevent panelists discriminating on the way the test was administered rather than on the samples. Panelists were ranked on their ability to discriminate between samples and the twenty candidates with the highest rankings were chosen for the training programme. Seven women and thirteen men were selected for the sensory panel. The age of panel members ranged from late teens to mid-forties, the majority of panelists being in their twenties.

4.2 Discussion Group Organisation

Because a panel of twenty members was felt to be too large for successful group discussion, the twenty panel members selected for this project were split into four groups. Two of the groups met together at each discussion session, the same two groups meeting together throughout one week. Four discussion sessions, each approximately thirty minutes in length, were held every week for all panel members. Over the twelve week period involved in the training programme, the groups were rotated such that all panel members came in contact with each other during discussion sessions. In this fashion, it was hoped to obtain a panel which functioned as a homogeneous unit.

During these discussion sessions the panel established the sensory attributes of whole milk powders which were to be measured in later, formal panel sessions. The way in which these sensory attributes were to be measured was also considered. This was particularly important with some of the appearance attributes. For example, should particle size be determined by appearance or by rubbing the powder between the fingers. A number of similar problems associated with the measurement of attributes were discussed by the group and suitable methods agreed upon.

At these sessions, the panel also considered mechanical problems relating to sample handling and presentation. The quantity of sample, both powders and reconstituted milk, was determined as well as the temperature at which samples were to be served. Sample containers and covers for the retention of aroma were discussed and decided upon. Suitable backgrounds to containers for the evaluation of colour were also considered. Thus, the methods used for sample handling and presentation were decided by the panel in an effort to find the optimum conditions for panel assessments and presentation techniques on which all panel members were agreed.

In this project, the role of panel leader was taken by the researcher. Since panel members had no previous experience with descriptive sensory analysis, it was not considered appropriate to appoint a panel leader from amongst them. In addition, the work of the panel leader takes up a considerable amount of time and it was considered that this was an unfair imposition on a full-time staff member of the Institute.

4.3 Selection of Sensory Attributes

At the first discussion session, the sensory panel was asked to look at whole milk powder samples, both as powders and as reconstituted milks, and think of words to describe the sensory properties. A glossary of terms, as suggested by Daget (1974) was not used for this session. However, several members of the panel had had considerable experience with whole milk powders and their experience was used to help put descriptions to sensory characteristics in the product. A long list of words for a variety of properties was obtained. This list included words such as: 'cream', 'yellowish', 'pale', 'grainy', 'fine', 'lumpy', 'fluffy', 'clinging', 'cohesiveness','sticky', 'coagulated', 'sweet', 'cooked', 'tallowy', 'creamy', 'fruity', 'perfumed', 'insipid', 'flat', 'chalky', 'astringency' and 'powdery'. From this list a summary of terms for the different characteristic was made. An effort was made to put these characteristics in the order in which a consumer might evaluate them. Cairncross and Sjostrom (1950) had emphasised the importance of having profile characteristics in the order in which they appeared in the product.

This summary of terms (as shown in Table 1) was presented to the panel at a second discussion session. The list of terms for properties in the dry powders was refined through discussion and an initial questionnaire produced for these terms (as shown in Table 2). Appearance attributes of colour and particle size in the powders were the first characteristics evaluated. The aroma of the powder was then estimated, characteristic notes of 'sweet', 'cooked' and 'tallowy' being identified. This was an expansion of the 'sweet' and 'cooked' notes listed in the initial summary. The lumpiness and the free-flowing properties of the powders were the last characteristics estimated. This limited the number of textural attributes estimated in the powder, the free-flowing properties describing a number of terms from the first summary - 'sticky', 'free-flowing', 'cohesiveness' etc. Thus, a number of terms were dropped from the initial summary and others added to form this questionnaire.

Table 1: Summary of Terms for Milk Powders (Session 1)

	Characteristic	Descriptions
Powder Characteristics		
Appearance	Colour	Cream, Yellowish, Pale
	Particle size	Grainy, Fine, Desiccated Coconut
	Lumpiness	Lumpy
	Powder Character	Fluffy, Non-settling
	Free-flowing Properties	Cohesiveness, Sticky, Clinging, Coagulated, Free-flowing
Aroma	Sweet	Sweet
	Cooked	Cooked
Reconstituted Milk Characteristics		
Appearance	Colour	
Aroma		Sweet
		Tallowy
Flavour		Sweet
		Tallowy
		Creamy
		Fruity
		Perfumed
		Essence-like
		Flat
		Insipid
		Watery
Texture (Mouthfeel)		Chalkiness
		Astringency
		Powdery

Table 2: Summary of Terms for Milk Powders (Session 2)

	A	B	C
Powder Characteristics			
Colour (White → Yellowish)	___	___	___
Particle Description) (Fine → Granular)	___	___	___
Aroma			
Sweet	___	___	___
Cooked	___	___	___
Tallowy	___	___	___
Lumpiness (No lumps → Very lumpy)	___	___	___
Free-flowing properties (Very cohesive → Very free-flowing)	___	___	___

At the next session, the panel concentrated on identifying further sensory attributes in the dry powders. The colour remained as the first attribute evaluated but it was decided that the aroma of the powder should be evaluated next in the profile. The panel identified six sensory characteristics in the aroma (expanded from three in the previous profile). These aroma notes included characteristics described with terms, such as 'sweet', 'fatty', 'dusty', 'solvent', 'tallowy' and 'lactone'. The order of the textural attributes in the powder was also changed, free-flowing properties being followed by the particle description and lumpiness of the powder (as shown in Table 3).

Table 3: Summary of Terms for Milk Powders (Session 3)

		A	B	C
Powder Characteristics				
Colour (White → Yellowish)		___	___	___
Aroma: 1. Sweet (Not sweet → Very sweet)				
2. Rancid Butter) Fatty) Sour Cream)	(Absent → Very Strong)	___	___	___
3. Milk Powder Factory, Dusty	(Absent → Very Strong)	___	___	___
4. Methyl ketone) Solvent)	(Absent → Very Strong)	___	___	___
5. Oxidised) Tallowy)	(Absent → Very Strong)	___	___	___
6. Lactone) Non-oxidised) Essency)	(Absent → Very Strong)	___	___	___
Free-flowing properties (Very cohesive → Very free-flowing		___	___	___
Particle Description	(Fine → Granular)	___	___	___
Lumpiness	(No lumps → Very lumpy)	___	___	___

In a similar way to the method used for establishing a profile of sensory attributes in the dry powders, a profile was established for sensory characteristics in the reconstituted milks. Terms were found to describe the aroma, colour, flavour and texture of the reconstituted milks (as shown in Table 4). Aroma characteristics of 'sweet' and 'buttery' were described with an additional category to include such terms as 'oxidised', 'non-oxidised', 'age-related' and 'taint'. The flavour attributes were described as 'sweet', 'creamy' and 'cooked' with an additional category similar to that included in the aroma profile. Textural attributes of 'viscosity', 'powderiness' and 'astringency' were also defined.

4.4 Sensory Profile used During First Dairying Season

Refinement of the original profile attributes was a continuous process throughout the training period. This resulted in the establishment of the questionnaire (as shown in Table 5) for the first dairying season. In this questionnaire, the colour and appearance characteristics were evaluated first before the aroma of the dry powder (this was a reversal of the order first suggested by the panel). The characteristics of aroma were limited to ones of 'sweetness', 'butteriness' and 'cooked/caramelised' which were thought to describe the aroma of fresh whole milk powder. In addition, an open category was left for any additional aroma characteristics. Attributes such as 'tallowy', 'rancid', 'essency', 'solvent' etc. were thought to be associated with stored whole milk powders rather than with the fresh powders to be evaluated during this project. However, it was felt that with a long project of this type, sufficient flexibility should be built into the sensory profile to allow for any unusual sensory attributes. In a similar way, the aroma and flavour

Table 4: Summary of terms (Session 4)

				A	B	C
Reconstituted Milk Characteristics						
Aroma	1.	Sweet	(Absent → Very Strong)	___	___	___
	2.	Buttery	(Absent → Very Strong)	___	___	___
	3.	Other (Specify): ______________	(Absent → Very Strong)	___	___	___
		May include: Oxidised (Tallowy, Carboard etc.) Non-oxidised (Perfumy, Essency etc.) Age-related (Musty, Stale etc.) Taints (Cowy, Weedy, Chemical etc.)				
Appearance		Colour	(White → Yellowish)	___	___	___
Flavour	1.	Sweet	(Absent → Very Strong)	___	___	___
	2.	Creamy	(Absent → Very Strong)	___	___	___
	3.	Cooked/Caramelised	(Absent → Very Strong)	___	___	___
	4.	Other (Specify): ______________		___	___	___
		______________		___	___	___
		______________		___	___	___
		May include (as for Aroma) Oxidised, Non-oxidised, Taints, Age-related flavours etc.)				
Texture	1.	Viscosity	(Thin → Very Thick)	___	___	___
	2.	Powderiness	(Slight → Pronounced)	___	___	___
	3.	Astringency	(Slight → Pronounced)	___	___	___

Table 5: Questionnaire used During First Dairying Season

Name ________________ Date ____________

In front of you are a number of milk powder samples. Please evaluate these for the following characteristics using a 0-10 scale where 0 = Absent
10 = Very Strong

	Sample Nos.			
	___	___	___	___
Powder Characteristics				
Colour (Creamy-white → Yellowish)	___	___	___	___
Free-flowing Properties (Very cohesive →Very free-flowing	___	___	___	___
Particle Description (Fine → Granular)	___	___	___	___
Aroma				
1. Sweetness (Not Sweet → Very Sweet)	___	___	___	___
2. Butteriness (Absent → Very Strong)	___	___	___	___
3. Cooked/Caramelised (Absent → Very Strong)	___	___	___	___
4. Other a. ____________	___	___	___	___
b. ____________	___	___	___	___
c. ____________	___	___	___	___

Comments

Table 5 (continued)

Reconstituted Milk Characteristics

	Sample Nos.			
	___	___	___	___
Aroma				
1. Sweetness (Not sweet → Very sweet)	___	___	___	___
2. Butteriness (Absent → Very strong	___	___	___	___
3. Cooked/Caramelised) (Absent → Very strong)	___	___	___	___
4. Other a. ________	___	___	___	___
b. ________	___	___	___	___
c. ________	___	___	___	___
Flavour				
1. Sweetness (Not sweet → Very sweet)	___	___	___	___
2. Creaminess (Not creamy → Very creamy)	___	___	___	___
3. Cooked/Caramelised (Absent → Very strong)	___	___	___	___
4. Other a. ________	___	___	___	___
b. ________	___	___	___	___
c. ________	___	___	___	___
Texture				
1. Viscosity (Thin → Thick)	___	___	___	___
2. Astringency (Absent → Very Strong)	___	___	___	___

Comments

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attributes of the reconstituted milks were identified and described. Characteristics of 'sweetness', 'butteriness' and 'cooked/caramelised' were identified in the aroma of the milk and again an additional category was allowed for other possible aroma characteristics. Similar characteristics were identifed in the flavour of reconstituted milks although the 'butteriness' attribute was replaced with one described as'creaminess'. Again, an additional category was included for other possible flavour notes in the milk. Textural attributes of 'viscosity' and 'astringency' were evaluated.

Several terms which had been initially described by the panel were dropped from this questionnaire. It was decided by the panelists that 'lumpiness' in the powders was a property found in stored whole milk powder rather than in fresh powders and this term was discarded as being irrelevant in this particular project. Panelists found little or no difference in the colour of the reconstituted milks (whereas obvious differences occurred in the colour of the powders) and it was decided to drop this attribute as being too difficult to measure effectively. The terms of 'powderiness' and 'astringency' were felt to be describing essentially the same attribute and the term 'astringency' only was retained in the questionnaire.

4.5 Sensory Profile used During Second Dairying Season

During the first dairying season it was discovered that, contrary to expectations, a number of additional aroma and flavour notes were occurring in certain powders. In particular, powders which contained added vitamins had distinctive aroma and flavour characteristics. It had been anticipated that 'sweet', 'buttery' and 'cooked' notes would be the major characteristics of aroma and flavour in whole milk powders, with a few possible additional notes occurring from time to time. Instead, the additional category included in the sensory profile became most important in differentiating between powders. In order to clarify and further define these differences during the second dairy season, this additional category was divided into six separate terms. These six terms included 'lactone', 'oxidised', 'feedy', 'vitaminized', 'taint' and 'age-related'. A lactone-like note had been defined in powders tested during the first season which was very similar to characteristic lactone notes found in stored gas-packed powders. Although not exactly the same as true lactone flavour, this note was very similar and was grouped under this category. Oxidised flavours, although not typical of fresh milk powders, were found to occur in certain powders particularly those fortified with a high level of iron. The iron acts as a catalyst in the oxidation process, causing the rapid onset of oxidised aroma and flavour notes in these particular powders. 'Feedy' or 'weedy' notes had been described in some milk powders, being noticeable in early season powders. A note characteristic of many vitaminized powders was also described during the first dairy season, the note defined by the panel being typical of powders fortified with a mixture of vitamins A, D, B_1 and C. A 'taint' category included notes occurring because of processing taints and 'age-related' described any 'musty' or 'stale' aroma or flavour notes present. This expanded sensory profile (as shown in Table 6) was used during the second dairying season.

Thus, over a period of some eighteen months, a profile was established which described the sensory properties of New Zealand whole milk powders. The sensory profile established for the first dairying season was believed to describe adequately sensory characteristics which might occur in whole milk powders. However, powders evaluated

Table 6: Questionnaire Used During Second Dairying Season

Name ____________ Date ________

In front of you are a number of milk powder samples. Please evaluate these for the following characteristics using a 0-10 scale where

0 = Absent
10 = Very strong

	Sample Nos.			
	____	____	____	____
Powder Characteristics				
Colour (Creamy-White → Yellowish)	____	____	____	____
Free-flowing properties (Very cohesive → Very free-flowing)	____	____	____	____
Particle Description (Fine → Granular)	____	____	____	____
Aroma				
1. Sweetness (Not sweet → Very sweet)	____	____	____	____
2. Butteriness (Absent → Very strong)	____	____	____	____
3. Cooked/Caramelised (Absent → Very strong)	____	____	____	____
4. Lactone ________	____	____	____	____
________	____	____	____	____
5. Oxidised ________	____	____	____	____
________	____	____	____	____
6. Feedy ________	____	____	____	____
________	____	____	____	____
7. Vitaminized ________	____	____	____	____
________	____	____	____	____

Comments

Table 6 (continued)

			Sample Nos.		
		____	____	____	____
8. Taint	________	____	____	____	____
	________	____	____	____	____
9. Age-related	________	____	____	____	____
	________	____	____	____	____
<u>Comments</u>					
<u>Aroma of the Reconstituted Milk</u>					
1. Sweetness (Not sweet → Very sweet)		____	____	____	____
2. Butteriness (Absent → Very strong)		____	____	____	____
3. Cooked/Caramelised (Absent → Very strong)		____	____	____	____
4. Lactone	________	____	____	____	____
	________	____	____	____	____
5. Oxidised	________	____	____	____	____
	________	____	____	____	____
6. Feedy	________	____	____	____	____
	________	____	____	____	____
7. Vitaminized	________	____	____	____	____
	________	____	____	____	____
8. Taint	________	____	____	____	____
	________	____	____	____	____
9. Age-related	________	____	____	____	____
	________	____	____	____	____

Table 6 (continued)

		Sample Nos.			
		____	____	____	____
Flavour of the Milk					
1. Sweetness (Not sweet → Very sweet)		____	____	____	____
2. Creaminess (Not creamy → Very creamy)		____	____	____	____
3. Cooked/Caramelised (Absent → Very Strong)		____	____	____	____
4. Lactone	________	____	____	____	____
	________	____	____	____	____
5. Oxidised	________	____	____	____	____
	________	____	____	____	____
6. Feedy	________	____	____	____	____
	________	____	____	____	____
7. Vitaminized	________	____	____	____	____
	________	____	____	____	____
8. Taint	________	____	____	____	____
	________	____	____	____	____
9. Age-related	________	____	____	____	____
	________	____	____	____	____
Texture of the Milk					
1. Viscosity (Thin → Very Thick)		____	____	____	____
2. Astringency (Absent → Very Strong)		____	____	____	____

Comments

during this dairying season differed somewhat from expectations. Because of this, adjustments were made to the profile, resulting in the sensory profile established for the second dairying season. During this second dairying season, this profile effectively described the sensory properties of whole milk powders and it was believed that a profile had been established which could be used for evaluating New Zealand whole milk powders. No attempt has previously been made to describe all the sensory properties of whole milk powder simultaneously, to give an integrated assessment of the sensory attributes of the product.

5. CONCLUSIONS

A sensory profile for New Zealand whole milk powders was successfully established. Of the sensory methods surveyed, descriptive sensory analysis had offered the most scope for the complete description of sensory properties in milk powders. A group of panelists was selected on the basis of their sensitivity to changes in whole milk powders. This group was used to establish the sensory profile of whole milk powders. Since it was not known which sensory properties are of importance to the consumer, an attempt was made to describe them all. The profile was established through a number of group discussions, the attributes and the order in which they appeared being established at this time. The profile was gradually refined through the training period before the first dairying season of evaluations. Some alterations were made to this profile before the second dairying season, as it was felt that some points required clarification.

The profile which was finally established was felt to give a comprehensive description of the sensory properties of New Zealand whole milk powders. It had proved possible to give a total evaluation of the sensory properties of the product, once a profile had been established in a systematic fashion. This method of evaluation took into account all possible properties which a consumer might evaluate and offered more flexibility than simple difference testing. It was possible to obtain a description of the attributes in a specific powder, these attributes could then be related to consumer requirements in a particular market-place. While the profile which was established was quite a complex one, it is believed that a simplified form of this method may offer more flexibility in the evaluation of commercial milk powders than the grading system in present use.

CHAPTER V

COMPARISON OF SENSORY SCALES

1. INTRODUCTION

A number of different scales have been used to quantify sensory attributes in foodstuffs. In this present study, three sensory scales were compared for their effectiveness in evaluating whole milk powders; a 0-10 linear category scale, a semi-structured linear scale and magnitude estimation scaling. One hundred and twelve whole milk powders were evaluated during the first season using each of the three scales.

The scales were compared using a number of criteria. Some criteria related to factors associated with the actual usage of the scale: ease of use, drift, problems with a moving baseline and the appearance of unexpected characteristics not present in the reference sample. Data produced by the three scales were studied for their sensitivity to sample differences, panel variance expressed as 'lack of fit' and the form of the sensory response when plotted against a physical measurement. Some of the sensory data were analysed to establish the effects which data transformation had on the sensitivity of the scale to sample differences. The sensory scales were also studied in relation to one another, to see whether they had been used by panelists in a similar fashion to measure the same sensory attributes.

2. BACKGROUND TO COMPARISON OF SCALES

Stevens and Galanter (1957) made one of the first detailed comparisons of category scales and magnitude estimation scaling. With 'prothetic' continua, such as heaviness, loudness and brightness, the category scale was concave downward when plotted against the ratio scale of subjective magnitude whereas the 'metathetic' continua, such as pitch and position, the category scale was linear when plotted in this way. Galanter and Messick (1961), in studying loudness, also found that the relationship between raw category and magnitude data seemed concave. Almost all studies of this relation between category and magnitude scales have shown that category scales lie between a linear and a logarithmic function for perceived intensity scales (Eisler 1962, Stevens and Galanter 1957).

Few workers have studied the comparative effectiveness of sensory scaling methods in measuring differences in foodstuffs. Moskowitz and Sidel (1971) compared the use of a 9-point hedonic scale with magnitude estimation scaling for studying the acceptability of foodstuffs. Both methods of scaling were about equally efficient in determining overall acceptability. When these scale functions were plotted against ingredient levels, it was clear that the two scales resembled one another. The magnitude scale did have the advantage that it measured how much more acceptable one food was over another. The relationship between hedonic values and magnitude estimates was plotted, showing a curvilinear relationship between these scales. Moskowitz and Sidel (1971) concluded that both evaluation procedures were equally sensitive to differences in food acceptability, but each procedure provided additional information as well. Magnitude scales quantified the ratios of food acceptability among different items, and the hedonic scale provided numerical and verbal categories of acceptance. McDaniel and Sawyer (1981a) also studied the sensitivity of magnitude estimation versus the 9-point hedonic scale in food preference testing. The use of magnitude estimation, as compared to the 9-point hedonic scale, resulted in more statistically significant differences in preference in both a home panel and a consumer laboratory panel. The scales were also compared for factors such as panel variability, within-panelist variability and sample-panel interactions.

McDaniel and Sawyer (1981b) also evaluated magnitude estimation versus category scaling as a sensory evaluation technique for use with sensory profiling. There was basically no difference in the judges' ability to generate differences by using either method. The number of significantly different samples was similar for both methods. However, there were significant differences between the scales when they were compared for panel variability. These differences were due to the normalization procedure used on the magnitude estimation data prior to analysis which effectively removed panel variance from these data. These workers considered that normalization of the category scaling data, although it would have reduced the panel variance, was unnecessary. There were also differences between the scales for other factors. The use of magnitude estimation resulted in far more panelist-sample interaction, while use of the category scale resulted in more panelist and replication variability.

In summary, a number of workers have compared sensory scales for 'pure' stimuli, such as loudness and brightness. Whether or not the relationships which have been found between scales for these relatively simple stimuli hold true when a more complex stimulus, such as a foodstuff, is considered has not been verified. Few comparisons of scaling techniques, when applied to foodstuffs, have been made. Where such comparisons have been made, they have often been comparisons of 'pure' stimuli, such as 'sweetness'. There have been few, if any, comparisons of scaling methods when used in association with a complex product profile, such as the one used in the present study to characterize New Zealand whole milk powders.

3. COMPARISION OF SENSORY SCALES

A comparison was made of the three sensory scales used to profile whole milk powders. The comparison was made on the basis of usage factors, such as ease of use, 'drift', problems with a moving baseline and the appearance of unexpected characteristics not present in the reference sample. Data produced by the three scales were studied for their sensitivity to sample differences, panel variance and the form of the sensory response when plotted against a physical measurement and when plotted against each other. Some data were also studied to see the effect which data transformation had on the sensitivity of the scale to sample differences.

3.1 Ease of Use

The use of the 0-10 linear scale caused panelists no problems. All members of the panel were used to the concepts of such numbers and had no difficulty in attaching appropriate numbers to samples, once suitable memory standards for the relative intensity of samples were established.

The semi-structured linear scale with an anchor point at either end, was the easiest of the scales for panelists to comprehend and use. This scale required no thought as to which number was appropriate to attach to a sample, merely an acknowledgement of the differences between samples in terms of distances on the line and some concept as to which samples could be considered 'strong' versus those considered to be 'weak'. Thus, although the use of numbers had been removed, this scale still relied upon the panelists' having memory standards for the range of intensities found in typical samples and where these lay in terms of distances on the line. This method, despite the fact that a memory standard was required, was the most direct scaling method, requiring the least conscious thought on the part of the panelist, merely the placing of a vertical mark on the appropriate portion of the line.

Of the three scaling methods, magnitude estimation scaling was the most difficult for panelists to use. Moskowitz (1974) described one aim of magnitude estimation scaling as being to have the panelist measure in the same way nature measures - with ratio scale values that have no arbitrarily limited endpoints. If this scaling method is so 'natural' one would expect panelists to find it very easy to use. However, although Stevens (1962) showed how sensory response could be described by a power function, this is not familar to panelists in everyday life. Moskowitz (1977c) divided panelists into those who are 'clear understanders', 'understanders' and 'non-understanders'. This is partially associated with the fact that scaling samples in multiples of a reference is a new and foreign concept to most panelists.

Perhaps, because three scales were in use at the same time and the panelists were constantly changing between scales, the difficulties involved in using magnitude estimation scaling were further emphasised. Both the 0-10 linear scale and the semi-structured linear scale were similar types of scales to use, but magnitude estimation because of its geometric nature was quite different. There was considerable comment from the panel that they found using magnitude estimation much more difficult than other scales and a few panelists tended to resent using it as a scaling method.

3.2 Drift

One problem associated with scaling methods which rely on a memory standard is that of 'drift'. This occurs when the panelist's memory standard is not constant but 'drifts' with time. This can occur with scales, such as the 0-10 linear scale and semi-structured linear scale which both rely on memory standards.

To see if 'drift' had occurred, data for both colour and viscosity measurements produced from these two scales were compared with instrumental measurements made over the whole season. If the 'drift' of the panel had been serious, one might have expected that the sensory estimates for colour and viscosity would not follow the same pattern as those measurements made using instrumental methods.

The means for the Yellowness Index (YI) of each month's powders showed that the colour of the powders declined steadily through the season with a slight (but not significant increase) during the eight month (as shown in Table 7). The same means for the sensory data from the 0-10 linear scale and the semi-structured linear scale also showed this decline through the season, although they exhibited an increase in the ninth month which was significant only in the data produced by the 0-10 linear scale. The sensory data were not as sensitive to change as the instrumental data, only those gross changes in colour which occurred in the first three months being

Table 7: Comparison of monthly means for colour measurements (instrumental and sensory) made on whole milk powders.

	MONTH								
	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
Yellowness Index (Hunterlab units)	36.5	35.6	34.4	33.1	32.4	30.4	30.7	30.9	30.1
β-Carotene (μg/g fat)	16.0	13.9	13.3	12.0	9.0	9.5	8.8	8.3	9.9
0-10 Linear Scale (Mean Scores)	5.8	5.0	4.7	4.5	4.7	4.5	4.3	4.6	5.2
Semi-structured Linear Scale (Mean scores)	6.1	5.2	4.7	4.3	4.4	4.4	4.1	4.2	4.5
Magnitude Estimation Scale (Geometric Means)	.198	.197	.206	.155	.163	.097	.099	.091	.070

significant. This was not unexpected as workers have reported previously that instrumental measurements of colour are more sensitive to slight changes in the colour of products then sensory measurements. The increase in the mean for the ninth month in both scales could indicate some 'drift' in the panel, interestingly it occurred in both scales. However, this increase in the ninth month also occurred in the means for β-carotene values in the same whole milk powders. Rather than 'drift' in the panel, this may suggest that what the panel perceived as colour was influenced more by the β -carotene value of the powder than by its Yellowness Index.

One might expect that this 'drift' would not occur in magnitude estimation scaling (presuming that the reference point remains constant). The colour of the reference powder used in this study remained reasonably constant (this was checked periodically by instrumental measurement) since it was sealed in light impermeable containers. In fact, the means for the magnitude estimation scaling showed a steadily decreasing trend throughout the season (similar to the trend showed by the Yellowness Index). However, the means were not significantly different in the first months of the season (as they were in the sensory data from the 0-10 linear and semi-structured linear scale). There was a significant drop in the mean for the fourth month and the means for the sixth, seventh, eight and ninth month were all significantly different (at the 1% level) from those of the first five months. Thus, the panel was able, with increasing ease, to differentiate between the reference sample and the monthly samples. When it is considered that the reference sample was an early season whole milk powder with high carotene content and thus, a high colour rating, this increasing ability to differentiate between samples was quite logical.

There was no increase in the colour of powders in the ninth month which had been indicated by the other sensory scales. Magnitude estimation, with its use of a reference powder, might have been expected to be more sensitive to seasonal changes in colour than other methods. This particular seasonal effect was not obvious when magnitude estimation scaling was used. Indeed, panelists were unable to differentiate significantly between samples produced in the first two months, when one of the most significant drops in the colour intensity was considered to have occurred using the 0-10 linear and semi-structured linear scales. Magnitude estimation scaling did not distinguish changes occurring in the colour during the early and late seasonal periods, which had been indicated by both instrumental methods and the other sensory scales.

A similar pattern was shown by means for viscosity measurements (both instrumental and sensory) made on the reconstituted milks (see Table 8). Means for the instrumental measurements of viscosity indicated that there was a significant rise in the viscosity of reconstituted milks at the end of the dairying season. The sensory means for the 0-10 linear scale followed the pattern of means from data produced by the capillary viscometer, the only sigificant increase in viscosity occurring in the ninth month. Means from the semi-structured linear scale followed those from data produced using the Ferranti-Shirley viscometer (at 10 000s^{-1}) showing a slight increase in both the eighth and ninth months. The means for magnitude estimation scaling showed no seasonal pattern.

To summarise; although 'drift' might have been expected to occur in the 0-10 linear and semi-structed scales which relied on memory standards, this was not apparent. Any differences in the seasonal pattern of means from these scales and those for magnitude estimation scaling appear

Table 8: Comparison of monthly means for viscosity measurements (instrumental and sensory) made on reconstituted milks.

	MONTH								
	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
Capillary viscometer (cps)	2.7	2.7	2.8	2.8	2.8	2.8	2.7	2.9	3.0
Ferranti-Shirley viscometer - 10 000 s^{-1} (cps)	2.9	2.8	2.8	2.9	2.8	2.8	2.8	3.0	3.0
0-10 Linear Scale (Mean Scores)	3.5	3.9	3.6	3.8	3.6	4.0	4.0	4.0	4.7
Semi-structured Linear Scale (Mean Scores)	3.7	3.7	3.7	3.5	3.8	3.9	3.9	4.5	4.4
Magnitude Estimation Scale (Geometric Means)	-.011	-.016	-0.008	-.012	-.012	.004	.019	.005	-.008

to have occurred in what the panel perceived, rather than in 'drift'. Magnitude estimation scaling, because of its use of a fixed reference point, could have been expected to be particularly sensitive to seasonal changes in the powders. On the contrary, this scale was less sensitive to these changes than the 0-10 linear and semi-structured linear scales which relied on memory standards.

3.3 Moving Baseline

The problem of a moving baseline or reference point has troubled sensory evaluation workers for many years, particularly in storage trials on foodstuffs. In such trials, a standard is often retained under near-ideal conditions and samples stored under conditions of high heat and humidity are tested against it. Often, the possibility that this reference point changes with time (albeit slowly) has not been considered, or if considered, the problem has not been resolved.

However, the possibility of a moving baseline when magnitude estimation scaling is used, does not appear to have been considered previously by sensory evaluation workers. Most studies which have used magnitude estimation have been of a short term nature and have not continued over a number of months as did the present study. In addition, workers using magnitude estimation have often used a number of reference standards, each standard representing a particular attribute. With the current study, it was felt that panelists were evaluating too many attributes for the use of individual references to be practicable, could successful standards be found.

It was decided that a whole milk powder would be used as the reference point. Because seasonal variation in the whole milk powders was being measured, it was necessary to take the reference point from the beginning of the season and use it throughout the nine months of the dairying season. The powder used as a reference was gas-packed into cans under nitrogen and stored at 4°C, these being considered conditions under which whole milk powder would retain its fresh properties for the longest period. However, even though the reference was stored under these conditions, the panel commented that, after about five to six months, it had begun to change, 'stale' and 'oxidised' flavours becoming noticeable. Thus, feedback from the panel indicated that the reference baseline was moving throughout the nine month period, although this movement became obvious to the panel only after several months of storage. The problem of a moving baseline when a single, stored reference sample was used was an unforeseen one and one which has not previously troubled workers using magnitude estimation. However, it is one factor which suggests that in this particular respect, magnitude estimation scaling was not a particularly appropriate scale for use in a long term seasonal study of the type carried out in the present project.

3.4 Missing Characteristics in the Reference

A difficulty arose with magnitude estimation scaling when panelists had to scale aroma or flavour characteristics not present in the reference whole milk powder. This proved to be a greater problem than had been anticipated at the beginning of the study.

It had been assumed that whole milk powders would have rather similar characteristics with some seasonal variation and the possibility of occasional 'other' attributes. In fact, it was found that many whole milk powders differed quite markedly in their aroma and flavour characteristics.

These 'other' aroma and flavour characteristics became key factors in distinguishing between different whole milk powders, particularly those containing additional vitamins and minerals. However, because the reference powder chosen for use with magnitude estimation scaling contained none of these vitamins and minerals, the typical aroma and flavour characteristics of these powders were not present in the reference. This confused many panelists and they reported considerable difficulty in evaluating quantitatively samples with aroma and flavour attributes not present in the reference sample. Thus, magnitude estimation is not an appropriate scale for an investigatory study in which all the attributes may not be clearly defined.

3.5 Sensitivity to Differences

In the past, sensory evaluation workers, such as McDaniel and Sawyer (1981b), have used the number of significant differences found between samples as one of the criteria for comparison between scaling methods. However, workers carrying out such a comparison between sensory scaling methods have generally created differences between samples by adding known levels of ingredients. Thus, workers have compared sensory estimates of samples which are known to differ in very specific ways. The present comparison of scaling methods was carried out during the evaluation of seasonal variation in commercial whole milk powders. Although it was believed that these commercial whole milk powders would change throughout the season and there might be some differences between powders processed differently, these differences were unknown. This created a difficulty in assessing the different sets of data, in that it was impossible to differentiate between 'real' significant differences occurring in the powders and 'imagined' differences which panelists believed were occurring.

With 112 milk powders, the number of significant differences could be used with some confidence to indicate the sensitivity of each scale to change in the samples. Data from the 0-10 linear scale showed more significant differences between samples (46) than the semi-structured linear scale (41). In addition, many of these statistical differences were found at a higher level of confidence in the 0-10 linear scale than in the semi-structured linear scale (see Tables 9 and 10). The use of magnitude estimation found somewhat fewer significant differences between samples (35) than the other two scales (see Table 11), possibly indicating less sensitivity in this scale to changes in the sample.

The three scales appear to have differentiated between samples in different ways. Magnitude estimation scaling was more sensitive to seasonal or monthly differences than to specification or factory effects. On the other hand, the semi-structured linear scale was more sensitive to specification differences than to monthly or seasonal differences. The 0-10 linear scale was sensitive to both seasonal and specification differences. This would indicate that the three scales were being used in somewhat different ways to measure the same sensory attributes. The use of a reference powder (even though it changed slightly) may have made magnitude estimation scaling more sensitive to the gradual seasonal changes in the powders. It is difficult to see why this scale did not distinguish well between different specification powders. This may have resulted

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NOTE: In all tables (unless otherwise stated)

NS indicates no significant differences

* indicates significance at the 5% level

** indicates significance at the 1% level

*** indicates significance at the 0.1% level

Table 9: Significant factors in the analyses of variance carried out on data from the 0 - 10 linear scale.

	Characteristic	FACTORY	SPECIFICATION	MONTH	LACK OF FIT
	Colour	***	***	***	***
	Free-Flowing Properties	***	***		***
	Particle Size		***		
AROMA OF THE POWDER	Sweetness	*	**	***	
	Butteriness		***	***	**
	Cooked/Caramelised			***	
	Lactone			**	
	Oxidised			*	
	Feedy				
	Taint			*	
	Age-Related		*	*	
AROMA OF THE RECONSTITUTED MILK	Sweetness		**	***	
	Butteriness			***	
	Cooked/Caramelised		**	***	
	Lactone		***		
	Oxidised		**	**	
	Feedy	***	**	**	
	Taint		***		
	Age-Related		*		
FLAVOUR OF THE RECONSTITUTED MILK	Sweetness	*	*	***	
	Creaminess	***	***	***	
	Cooked/Caramelised		***	***	
	Lactone		***		
	Oxidised		***		
	Feedy	*	***		
	Taint		**	**	
	Age-Related				
	Viscosity			***	
	Astringency			***	

Table 10: Significant factors in the analyses of variance carried out on data from the semi-structured linear scale.

	Characteristic / FACTOR	FACTORY	SPECIFICATION	MONTH	LACK OF FIT
	Colour	***	***	***	***
	Free-Flowing Properties	**	***	***	***
	Particle Size	*	***	***	
AROMA OF THE POWDER	Sweetness		**	**	
	Butteriness		***	***	***
	Cooked/Caramelised				***
	Lactone			*	
	Oxidised		*		
	Feedy				
	Taint	*	*	*	
	Age-Related		*		
AROMA OF THE RECONSTITUTED MILK	Sweetness		***		
	Butteriness				**
	Cooked/Caramelised	*	***	**	**
	Lactone		**		
	Oxidised		***		
	Feedy				
	Taint	*	**		
	Age-Related		***		
FLAVOUR OF THE RECONSTITUTED MILK	Sweetness			**	
	Creaminess	*	***		
	Cooked/Caramelised		*	**	*
	Lactone		***	**	
	Oxidised				
	Feedy				
	Taint		*		
	Age-Related		***		
	Viscosity		**	***	*
	Astringency		*	*	

Table 11: Significant factors in the analyses of variance carried out on data from magnitude estimation scaling.

	Characteristic / FACTOR	FACTORY	SPECIFICATION	MONTH	LACK OF FIT
	Colour	***	***	***	***
	Free-Flowing Properties	**	***	***	***
	Particle Size	*	***	*	*
AROMA OF THE POWDER	Sweetness				
	Butteriness		*		**
	Cooked/Caramelised	*	*		
	Lactone			*	
	Oxidised				
	Feedy				
	Taint				
	Age-Related				
AROMA OF THE RECONSTITUTED MILK	Sweetness		**		
	Butteriness				
	Cooked/Caramelised	*	**	*	
	Lactone			**	
	Oxidised			**	
	Feedy	**		**	
	Taint			***	
	Age-Related			***	
FLAVOUR OF THE RECONSTITUTED MILK	Sweetness		**	**	
	Creaminess		**	***	
	Cooked/Caramelised		**	**	**
	Lactone		**		
	Oxidised		*	**	
	Feedy		*		
	Taint			**	
	Age-Related				
	Viscosity				
	Astringency			**	

from the difficulties encountered by panelists in scaling characteristics not present in the reference powder, as these 'additional' characteristics were vital in distinguishing between different specification powders. The semi-structured linear scale was used with ease by the panel to scale the 'additional' aroma and flavour attributes. There was a tendency for panelists to 'over-react' when using this scale, swinging violently from one end of the scale to another. This resulted in rather more panel variance when this scale was used and may have meant that more gradual seasonal changes were lost whereas dramatic differences between specifications were indicated. The 0-10 linear scale, because the number concept was clear in the panelists' minds, seemed to distinguish both seasonal and specification differences.

3.6 Lack of Fit

The 'lack of fit' term (see Tables 9, 10 and 11) indicates how well the samples are explained in terms of the main effects, that is in terms of month, specification and factory effects.

As this study was carried out on commercial milk powders processed throughout the dairying season, the data were very scattered. Because of this, data could be analysed for the main effects only and not for the interactions. A significant 'lack of fit' figure may indicate possible interactions which cannot be tested for. For example, in the analysis of colour for all three scales, there was a highly significant (at the 0.1% level) 'lack of fit' value. Since this occurs across all three scales, it may well indicate that there are significant but unknown interactions taking place.

When this 'lack of fit' figure is significant for one scale and not for another, it would seem to indicate that that particular scale is not as effective in explaining variance occurring in the samples because of greater panel variability. From Tables 9, 10 and 11 it can be seen that there were very few significant 'lack of fit' figures for data from the 0-10 linear scale, a few more significant figures for data from magnitude estimation and rather more for data from the semi-structured linear scale. The scales were evenly matched in their ability to describe variance in samples for their appearance but in the description of aroma and flavour characteristics the 0-10 linear scale was rather more effective than either the semi-structured linear scale or magnitude estimation scaling.

3.7 Analysis of Single Sessions

Separate analyses of variance were carried out on several attributes evaluated at five sensory panel sessions held during the mid-seasonal period. A two way analysis of variance was carried out to estimate differences between samples and differences occurring between panelists.

These analyses indicated that there was more panel variance in the data produced from the 0-10 linear scale and the semi-structured linear scale than in data produced by magnitude estimation (see Tables 12, 13, 14, 15 and 16). This might have been expected, since magnitude estimation was the only scale in which a fixed reference point was given. However, magnitude estimation scaling was not superior to the other two scales in differentiating between samples. All three scales demonstrated similar numbers of differences between samples.

Table 12: Summary of analyses of variance carried out on colour data (untransformed and transformed) from five sensory sessions for all three sensory scales.

TABULATED F VALUES AND SIGNIFICANCE LEVELS

0-10 Linear Scale:

	Untransformed Data					Transformed Data				
Session	1	2	3	4	5	1	2	3	4	5
Sample	*** 33.96	*** 22.84	*** 18.72	** 6.22	*** 26.59	*** 25.49	*** 23.69	*** 18.39	* 5.82	*** 26.75
Panelist	*** 6.96	** 3.96	*** 10.71	** 4.96	NS 1.14	NS 0.11^{-3}	NS 0.20^{-3}	NS 0.20^{-3}	NS 0.15^{-4}	NS 0.73^{-4}

Semi-Structured Linear Scale:

	Untransformed Data					Transformed Data				
Session	1	2	3	4	5	1	2	3	4	5
Sample	*** 27.03	*** 9.78	*** 21.84	* 5.28	*** 20.34	*** 33.08	*** 10.28	*** 17.91	** 6.10	*** 22.95
Panelist	*** 10.51	* 2.50	*** 10.93	* 2.57	NS 2.30	NS -0.79^{-5}	NS -0.67^{-5}	NS 0.14^{-4}	NS 0.23^{-4}	NS 0.16^{-4}

Magnitude Estimation Scaling:

	Untransformed Data					Transformed Data				
Session	1	2	3	4	5	1	2	3	4	5
Sample	*** 7.34	*** 15.80	*** 14.48	** 9.27	*** 16.28	*** 7.34	*** 15.80	*** 14.48	** 9.27	** 16.28
Panelist	** 3.27	*** 6.64	*** 10.03	*** 6.33	* 3.60	NS -0.19^{-6}	NS 0.00	NS 0.33^{-6}	NS 0.18^{-6}	NS -0.63^{-6}

Table 13: Summary of analyses of variance carried out on sweetness (aroma of the powder) data (untransformed and transformed) from five sensory sessions for all three sensory scales.

TABULATED F VALUES AND SIGNIFICANCE LEVELS

0-10 Linear Scale:

	Untransformed Data					Transformed Data				
Session	1	2	3	4	5	1	2	3	4	5
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sample	1.07	1.72	1.47	1.20	0.28	1.40	1.85	1.18	0.97	0.18
	***	NS	***	***	NS	NS	NS	NS	NS	NS
Panelist	5.84	1.71	5.17	6.05	1.61	0.25^{-4}	0.00	0.27^{-5}	0.32^{-4}	0.39^{-4}

Semi-Structured Linear Scale:

	Untransformed Data					Transformed Data				
Session	1	2	3	4	5	1	2	3	4	5
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sample	0.27	1.50	0.56	0.39	2.43	0.40	1.59	0.37	0.52	1.28
	NS	***	**	NS	*	NS	NS	NS	NS	NS
Panelist	2.21	9.22	3.55	2.05	3.06	0.70^{-5}	0.24^{-3}	0.65^{-4}	0.12^{-4}	0.16^{-4}

Magnitude Estimation Scaling:

	Untransformed Data					Transformed Data				
Session	1	2	3	4	5	1	2	3	4	5
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sample	1.11	2.06	2.79	1.01	1.80	1.11	2.06	2.79	1.01	1.80
	**	**	***	**	**	NS	NS	NS	NS	NS
Panelist	4.43	3.35	6.21	3.60	3.81	0.43^{-7}	0.00	0.86^{-7}	-0.24^{-7}	-0.39^{-7}

Table 14: Summary of analyses of variance carried out on sweetness (aroma of the milk) data (untransformed and transformed) from five sensory sessions for all three sensory scales.

TABULATED F VALUES AND SIGNIFICANCE LEVELS

0-10 Linear Scale:

	Untransformed Data					Transformed Data				
Session	1	2	3	4	5	1	2	3	4	5
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sample	0.70	2.20	1.32	0.17	0.47	0.64	2.61	1.54	0.32	0.94
	***	***	***	**	**	NS	NS	NS	NS	NS
Panelist	8.64	8.08	22.38	4.03	4.63	0.00	0.45^{-4}	0.24^{-4}	0.58^{-5}	0.44^{-4}

Semi-Structured Linear Scale:

	Untransformed Data					Transformed Data				
Session	1	2	3	4	5	1	2	3	4	5
	NS	NS	NS	*	NS	NS	NS	NS	*	NS
Sample	2.02	0.73	1.44	4.95	0.02	1.39	1.09	0.33	4.62	0.22
	***	**	***	*	**	NS	NS	NS	NS	NS
Panelist	8.09	4.14	8.22	2.70	4.17	0.10^{-2}	0.85^{-5}	0.39^{-4}	0.12^{-4}	0.60^{-4}

Magnitude Estimation Scaling:

	Untransformed Data					Transformed Data				
Session	1	2	3	4	5	1	2	3	4	5
	NS	NS	*	NS	NS	NS	NS	*	NS	NS
Sample	1.40	2.32	3.47	3.53	1.26	1.40	2.32	3.47	3.53	1.26
	*	***	**	NS	**	NS	NS	NS	NS	NS
Panelist	2.48	5.59	3.22	1.59	4.42	0.15^{-6}	0.83^{-7}	0.28^{-6}	0.18^{-6}	-0.95^{-7}

Table 15: Summary of analyses of variance carried out on sweetness (flavour of the milk) data (untransformed and transformed) from five sensory sessions for all three sensory scales.

TABULATED F VALUES AND SIGNIFICANCE LEVELS

0-10 Linear Scale:

	Untransformed Data					Transformed Data				
Session	1	2	3	4	5	1	2	3	4	5
	NS	NS	NS	NS	NS	NS	NS	NS	*	NS
Sample	0.74	0.41	1.91	2.49	2.55	0.73	0.29	2.43	3.75	1.32
	***	*	***	***	***	NS	NS	NS	NS	NS
Panelist	7.60	3.00	6.21	6.04	8.26	-0.65^{-5}	0.30^{-5}	0.00	0.43^{-4}	0.63^{-4}

Semi-Structured Linear Scale:

	Untransformed Data					Transformed Data				
Session	1	2	3	4	5	1	2	3	4	5
	*	*	*	NS	NS	NS	*	NS	NS	NS
Sample	3.12	3.46	3.50	1.05	2.87	1.41	3.77	2.00	0.43	1.55
	***	***	***	**	***	NS	NS	NS	NS	NS
Panelist	5.86	5.99	12.68	4.41	6.94	0.53^{-5}	0.31^{-5}	0.24^{-4}	0.27^{-4}	0.06

Magnitude Estimation Scaling:

	Untransformed Data					Transformed Data				
Session	1	2	3	4	5	1	2	3	4	5
	*	NS	NS	NS	NS	*	NS	NS	NS	NS
Sample	3.86	0.38	1.50	0.49	0.05	3.86	0.38	1.80	0.49	0.05
	**	NS	*	NS	NS	NS	NS	NS	NS	NS
Panelist	3.65	2.15	3.01	0.61	0.72	0.15^{-6}	0.18^{-7}	0.12^{-6}	-0.28^{-7}	-0.63^{-9}

Table 16: Summary of analyses of variance carried out on viscosity data (untransformed and transformed) from five sensory sessions for all three sensory scales.

TABULATED F VALUES AND SIGNIFICANCE LEVELS

0-10 Linear Scale:

	Untransformed Data					Transformed Data				
Session	1	2	3	4	5	1	2	3	4	5
	NS	NS	NS	NS	*	NS	NS	NS	NS	**
Sample	1.46	0.60	0.41	0.31	6.00	2.45	0.67	0.24	0.37	7.63
	***	***	*	NS	***	NS	NS	NS	NS	NS
Panelist	35.79	6.22	2.56	1.01	5.84	0.25^{-4}	0.54^{-4}	0.14^{-4}	0.15^{-4}	0.75^{-2}

Semi-Structured Linear Scale:

	Untransformed Data					Transformed Data				
Session	1	2	3	4	5	1	2	3	4	5
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sample	0.49	1.72	1.18	3.00	3.30	0.56	1.83	0.70	2.84	3.12
	***	***	***	NS	**	NS	NS	NS	NS	NS
Panelist	4.59	5.74	5.82	1.80	5.36	0.24^{-5}	0.75^{-5}	0.45^{-5}	0.27^{-4}	0.22^{-4}

Magnitude Estimation Scaling:

	Untransformed Data					Transformed Data				
Session	1	2	3	4	5	1	2	3	4	5
	*	NS	NS	NS	NS	*	NS	NS	NS	NS
Sample	3.19	1.51	1.10	0.39	0.48	3.19	1.51	1.10	0.39	0.48
	***	**	***	*	*	NS	NS	NS	NS	NS
Panelist	5.02	4.39	4.78	3.13	2.70	0.00	0.12^{-6}	0.99^{-7}	-0.37^{-7}	0.00

Transformations of the data were then carried out to see whether transformations which reduced panel variance would increase the efficiency of a scale to differentiate between samples. There are two common ways in which data can be transformed. In the first method, the panelist scores are multipled by the overall mean for the session and divided by the individual panelist's mean.

$$\text{Panelist Score} \times \frac{\text{Overall Mean}}{\text{Panelist Mean}} = \text{Transformed Score}$$

This transformation takes each panelist's data and sets it around the overall mean for the session. The panel means are adjusted so that they are the same, yet the proportional distance between the samples is maintained. It is also possible to adjust the panel values by adding a number to each value such that they are all moved to a similar portion of the scale but the relative distances between samples are maintained. Moskowitz and Sidel (1971) used this method in their 'normalization' of data from the 9-point hedonic scale ratings. One can argue in favour of both methods of transformation. The first method retains the proportional distance between samples which a panelist may have expressed over only a small portion of the scale, the second moves the panelists' ratings to the same portion of the scale but constrains them to the relative distances which they have previously indicated. Both approaches are satisfactory but it was decided to use the first method of transformation to avoid any problems with 'bunching' of the data which may result from the second method of transformation.

The use of this transformation method on selected sensory data from the 0-10 linear and semi-structured scales, led to the reduction of panel variance to a non-significant level but did little to increase the differentiation between samples. In a few cases, notably in data from the semi-structured linear scale, significant differences between samples were reduced. This occurred where a panelist used only a narrow range at the bottom end of the scale and tended to score at the extremes of this narrow range. When these scores were transformed, the very low values became only very slightly larger but the upper values became very large indeed. Thus, differences which had been spread over a relatively small portion of the scale were now positioned at either end of the scale. These distortions to the scale reduced some significant differences between samples to a non-significant level.

The magnitude estimation data presented a slightly different problem because of the geometric nature of the scale. Logarithms of the magnitude estimations were used in the analysis of variance of these data, because of the skewed distribution which this type of geometric scale produces (Moskowitz 1974). To transform the data, a method of 'modulus equalization', described by Moskowitz (1977b), was used in which the panelist's estimates were adjusted such that the geometric mean across samples was 1.0. This adjustment retained the relative distance between samples, merely reduced the panel variance. This can be seen in the analyses of variance for the transformed data from magnitude estimation scaling in which the F value for the samples remained the same in both untransformed and transformed data. Only the F values for the panel changed to a non-significant level in the transformed data.

Transformation of the raw sensory scores was not found to aid the effectiveness of these sensory scales. Certainly, the significance of the panel variance was reduced to a non-significant level. However, the efficiency of the scale in differentiating between samples was not increased and in some cases was reduced. This was especially true where the sample differences were only marginally significant. In situations, where samples are rather similar, it would seem to be particularly dangerous to carry out data transformation. Such practices may lead to incorrect conclusions being drawn from the data. In general, it would seem to be better practice to use the untransformed, unaltered data, accepting a certain level of panel variance as normal.

3.8 Sensory Response Plots

Analysis of variance is carried out on sensory data on the assumption of the linearity of the scales. Psychologists, such as Stevens (1962), have shown that the sensory response to increasing intensities of stimuli is often, in fact, described by a curve which flattens out as the stimuli intensity becomes very great. Although it was not possible to plot sensory estimates against an objective or instrumental measurement for all attributes, this could be done for the measurement of colour in whole milk powders.

Mean sensory estimates for colour were plotted against Yellowness Index (YI) measurements. These plots showed (see Figure 2) that, in each case, the sensory response to increasing stimulus intensity was a linear one over the range which had been measured. The plot for the semi-structured linear scale indicated a more even spread of data over the scale range than the other two scales in which the data was somewhat 'bunched' in the centre. However, the linearity of response over the range tested was true for all scales, indicating that analysis of variance was an appropriate method of statistical analysis for these data. It also indicated that the scales were working in a similar fashion for this attribute.

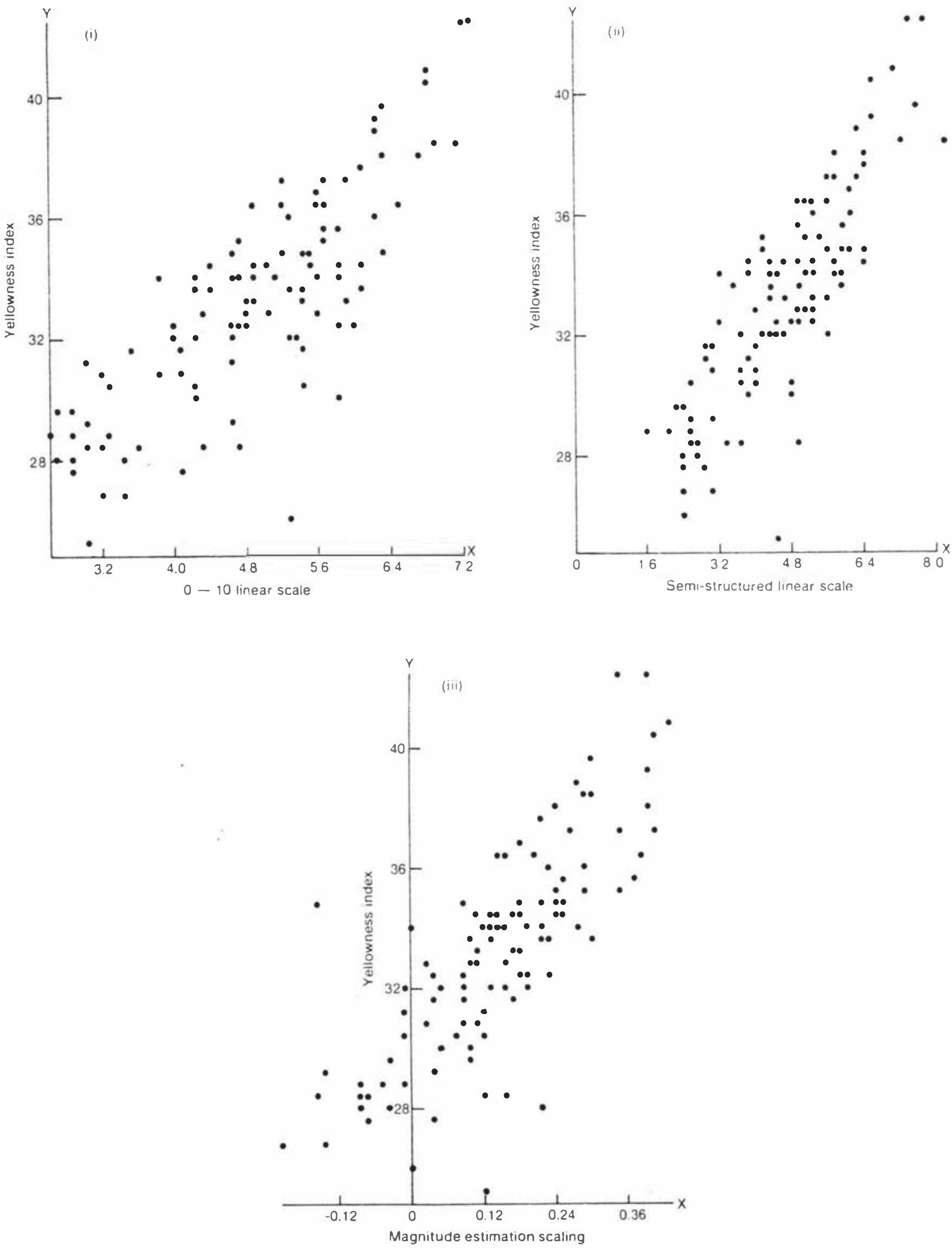

Figure 2: Sensory estimates of colour made using a 0-10 linear scale, a semi-structured linear scale and magnitude estimation scaling plotted against Yellowness Index measurements made using a Hunterlab D25 colorimeter.

3.9 Correlation of Data from Sensory Scales

A method used by some authors, such as Galanter and Messick (1961), to compare different sensory scales has been to plot the values from one scale against another. If the two scales are being used by the panel in the same fashion, the relationship between the two scales should be a linear one. The data obtained for each sensory attribute were correlated one with another to see whether the relationships between scales were, in fact, linear.

These correlations showed (see Table 17) that the relationships between the three scales for the physical attributes of the powder (colour, free-flowing properties and particle size) were quite close. The relationship between the 0-10 linear and semi-structured scales for colour was highly significant (r = 0.892) indicating that the panel used both these scales in a very similar way to quantify the colour of the powder. Relationships between these two scales and magnitude estimation scaling were also significant but not as high, indicating that the panel used magnitude estimation scaling in a slightly different fashion to indicate the colour of the powders. Correlations between scales for assessments of free-flowing properties and particle size in whole milk powders were also high.

The correlation coefficients for aroma and flavour attributes in both powders and reconstituted milks did not show the close relationships indicated in the physical properties of powder appearance (see Table 17). Many of these correlation coefficients were not significant and none of them were as high as those for the physical properties. Only when the attribute was a very distinctive one, such as the lactone-like, oxidised and age-related notes, did the panel begin to use these scales in a similar fashion. Textural properties, such as viscosity and astringency were not measured in the same way with these three scales.

Table 17: Summary of correlation coefficients for direct correlations between sensory scales

Attribute	0-10 Linear/ Semi-structured Linear	0-10 Linear/ Magnitude Estimation	Semi-structured Linear/ Magnitude Estimation
Colour	0.892 ***	0.696 ***	0.681 ***
Free-flowingness	0.850 ***	0.781 ***	0.780 ***
Particle size	0.887 ***	0.859 ***	0.893 ***
<u>Aroma of Powder</u>:			
Sweetness	0.221 *	0.255 **	0.276 **
Butteriness	0.368 ***	0.417 ***	0.391 ***
Cooked/Caramelised	0.152 NS	0.214 *	0.156 NS
Lactone	-0.080 NS	0.111 NS	0.105 NS
Oxidised	0.143 NS	0.105 NS	0.195 *
Feedy	0.148 NS	0.108 NS	-0.083 NS
Taint	0.141 NS	0.193 *	0.165 NS
Age-related	0.564 ***	0.525 ***	0.477 ***
<u>Aroma of Milk</u>:			
Sweetness	0.297 **	0.184 NS	0.364 ***
Butteriness	0.049 NS	-0.179 NS	0.182 NS
Cooked/Caramelised	-0.037 NS	0.290 **	0.226 *
Lactone	0.432 ***	0.213 *	0.278 **
Oxidised	0.266 **	0.401 ***	0.222 *
Feedy	-0.057 NS	0.069 NS	0.206 *
Taint	0.423 ***	0.110 NS	0.051 NS
Age-related	0.227 *	0.157 NS	-0.008 NS
<u>Flavour of Milk</u>:			
Sweetness	0.351 ***	0.276 **	0.361 ***
Creaminess	0.359 ***	0.325 ***	0.395 ***
Cooked/Caramelised	0.112 NS	0.288 **	0.305 **
Lactone	0.711 ***	0.564 ***	0.570 ***
Oxidised	0.508 ***	0.473 ***	0.446 ***
Feedy	-0.110 NS	0.359 ***	-0.078 NS
Taint	0.547 ***	0.338 ***	0.367 ***
Age-related	-0.074 NS	0.074 NS	-0.023 NS
Viscosity	0.189 NS	0.137 NS	0.030 NS
Astringency	0.266 **	0.209 *	0.136 NS

Workers, such as Stevens and Galanter (1957) and Galanter and Messick (1961), found that relationships between sensory scales were typically linear or curvilinear. Some linear relationships were found between the scales in the physical attributes of whole milk powders, such as colour and particle size (see Figures 3 and 4). However, no curvilinear relationships were obvious in these data. When the data from more complex attributes were studied, such as the buttery note in the aroma of the milk, there were no clear relationships between the sensory scales (see Figure 5).

The task of appearance measurement is obviously consistent across all three scales and all three were being used in a similar fashion. However, in the evaluation of aroma and flavour there was something about the task which caused the panelist to use the three scales in quite different ways. The 0-10 linear ard semi-structured scales appear to be more closely related to each other than to the magnitude estimation scale. This abrupt change in the way in which the scale is used from one sensory attribute to another suggests that it may be dangerous to presume that because a scale functions in a particular manner for one attribute, it functions in a similar manner for all attributes. This is particularly true of magnitude estimation scaling, in which a power function has been found to describe the data for certain physical attributes. While these power functions may hold for these physical attributes, it is possible that they do not hold for more complex aroma and flavour attributes.

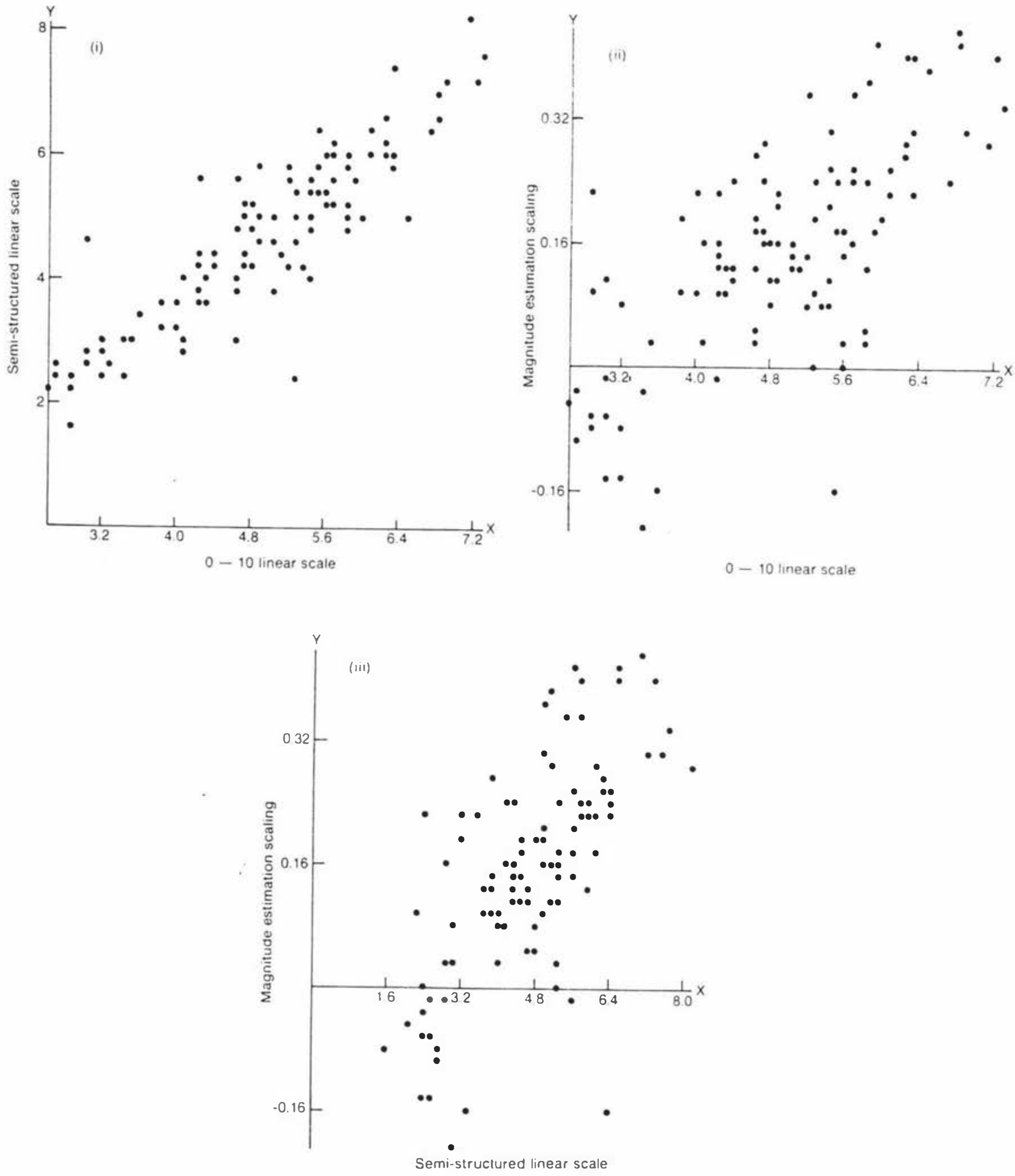

Figure 3: Sensory estimates of colour made using a 0-10 linear scale, a semi-structured linear scale and magnitude estimation scaling plotted against one another.

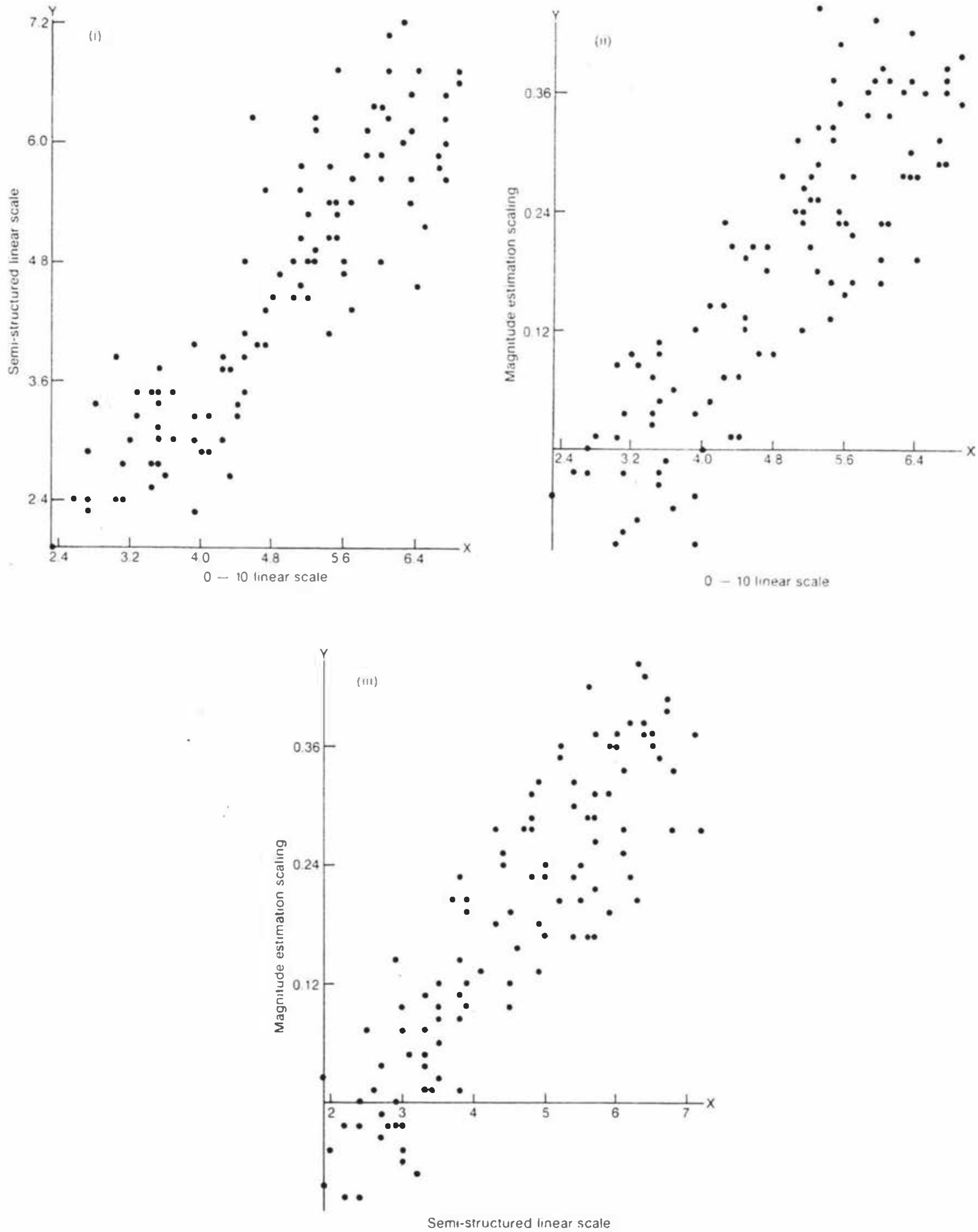

Figure 4: Sensory estimates of particle size made using a 0-10 linear scale, a semi-structured linear scale and magnitude estimation scaling plotted against one another.

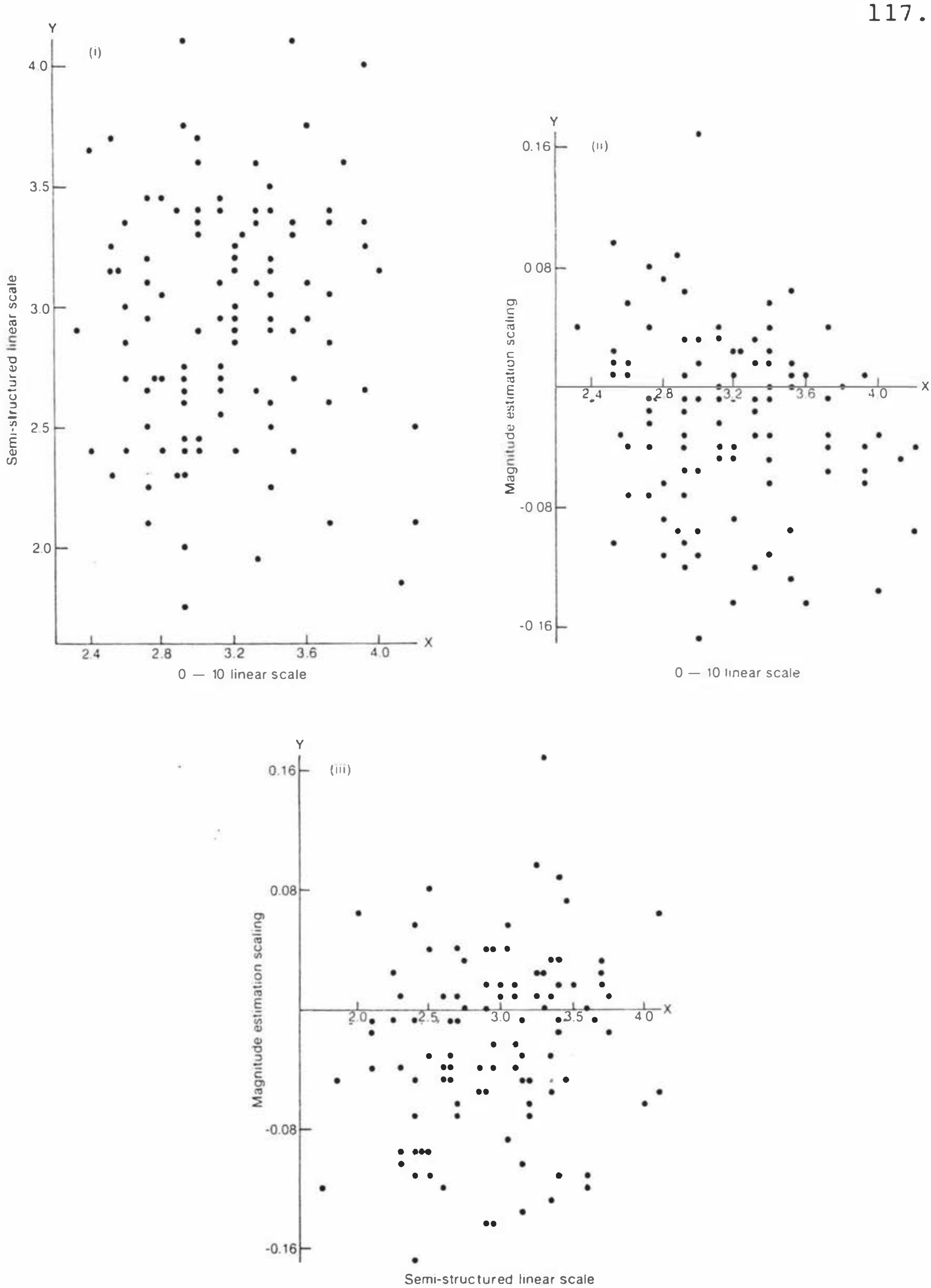

Figure 5: Sensory estimates of butteriness in the aroma of the reconstituted milks made using a 0-10 linear scale, a semi-structured linear scale and magnitude estimation scaling plotted against one another.

4. SUMMARY AND CONCLUSIONS

Despite the fact that magnitude estimation scale has been the choice of sensory workers in recent years, in this particular project it was the least effective sensory scale both for usage and sensitivity. The use of this scale posed some problems because the whole milk powder used as a reference changed slightly over the nine months of the dairying season. There were other problems associated with unexpected characteristics arising in samples which were not present in the reference sample. Magnitude estimation scaling was not effective in this type of investigatory study in which all the attributes were not clearly defined. In addition, the scale was not as sensitive to sample differences as the other two scales. The semi-structured linear scale was easy to use but not very effective at differentiating between samples. More 'lack of fit' occurred in data from this scale (suggesting the possibility of greater panel variance) and transformations of the data reduced sample differences to a non-significant level in some cases. The 0-10 linear scale was easy to use and appeared sensitive to changes in the samples, very little 'lack of fit' occurring.

A summary of the results of these comparisons has been made in Table 18.

Table 18: Comparison of three sensory scales used to evaluate whole milk powders during the first dairying season.

	Scale		
	0-10 linear	Semi-structured Linear	Magnitude Estimation
Ease of Use	**	**	*
'Drift'	***	***	***
Moving Baseline	***	***	*
Missing Characteristics	***	***	*
Nos. Differences	***	**	*
'Lack of Fit'	***	*	**
Single Sessions	***	***	***
Transformed Data	***	*	**
Sensory Plots	**	***	**

Scales have been awarded three, two and one star ratings as to their effectivensss in each category in which a comparison was made. For the reasons outlined above, the 0-10 linear scale was chosen as the only sensory scale for use in the second dairying season.

CHAPTER VI

COMPARISON OF SENSORY AND OBJECTIVE DATA

1. INTRODUCTION

One aim in the present research was to study the sensory data in relation to objective measurements made on whole milk powders. If changes in product characteristics measured by instrumental methods are related to sensory characteristics, it is possible to measure these sensory characteristics more quickly and more economically by instrumental means than by the use of sensory panels (Corey 1970).

Objective measurements were made to characterize the colour and particle size distribution of the different powders and to measure viscosity in the reconstituted milks. It was considered to be outside the scope of this study to engage in highly complex chemical analyses of aroma and flavour compounds.

A comparison was made of the relevant sensory data with these instrumental measurements. Data from the first dairying season were used as the basis for the comparison between the objective and sensory measurements. One hundred and twelve milk powders were tested during this period, using both sensory and objective methods. Data from all these powders were used for the comparisons. To begin with, simple relationships were sought between data for relevant sensory attributes in milk powders and single measurements made on the same samples. Multiple regression techniques were then used to study the sensory data in relation to a number of instrumental measurements, to see which combination of objective measurements best expressed sensory perception of an attribute.

2. BACKGROUND TO COMPARISON OF SENSORY AND OBJECTIVE MEASUREMENTS

In studying relationships between sensory and objective measurements, the ultimate aim is to establish mathematical equations which permit the scientist to predict sensory characteristics from physical measurements. In deciding which measurements to make, the more precisely the individual parameters are defined both in sensory and physical terms, the greater the probability of developing suitable objective tests (Kramer 1972).

Objective measurements have a basic disadvantage in that they do not measure sensory properties as a human respondent does. Consequently, they are accurate only to the extent that they are analogous to the human sensory response. On the other hand, once calibrated precisely, they are not subject to drift, fatigue or other psychological errors to which human subjects are prone (Kramer and Szczesniak 1973).

In making objective measurements, certain arbitrary decisions have to be made as to what is measured and under what physical and environmental conditions measurements are made. Measurements may be of well defined physical properties, such as colour, which relate directly to what the consumer perceives. Measurements can also be of an indirect nature, such as measurements of fat content in cottage cheese dressing to predict texture in the final product. It is necessary to make a decision as to which instrumental measurements relate to which quality attributes. This decision, although based on the researcher's data, is an arbitrary one. This means that there are several sources of error and consequently limitations in the use of the data finally gained: the errors inherent in the definition and measurement of physical parameters, the errors inherent in the definition and measurement of sensory parameters and the errors made in the decision as to which measurement should be correlated with another. Each step must be made with great care in order to gain results which can be considered reasonably valid under such imperfect conditions.

2.1 Appearance

Visual perception by the observer is a result of how the eye interprets the light reaching it from objects. It is important to determine which factors influence the visual appearance of foodstuffs and to establish scales for each relevant factor. Preferably, this should be an instrumentally determined scale which can be correlated with what is perceived. The visual appearance of any object is affected by its chromatic properties (to do with colour) and its geometric properties (to do with the geometric distribution of light.) Appraisal of appearance characteristics is complicated by the fact that surfaces deviate from the ideal. They vary markedly in their degree of opacity and are rarely smooth or homogeneously pigmented (Mackinney et al. 1966).

Visual perception of texture in foodstuffs is an important aspect of appearance measurements. Baldwin (1977) believed that the geometric or textural aspects of appearance in whole milk powders were very important especially in the production of powder for direct consumer use. A free-flowing powder is considered to be very desirable to the consumer. Little attempt has been made to relate aspects of visual appearance which influence the consumer's expectation for a particular milk powder with instrumental measurements.

2.2 Viscosity

The texture of foods is, perhaps, the least well-described of its many sensory properties. The activity which brings about perception of texture in the mouth is to some extent an automatic one and all the sensory activity does not necessarily penetrate into the consciousness. This means that apart from the associated emotional reactions, responses are often evoked at a fairly involuntary physiological level as in the rejection of food or the automatic initiation of the next stages of ingestion.

In the evaluation of viscosity, studies suggest that the shear rate operating in the mouth during the assessments of fluids varies with the viscosity. Low viscosity fluids, such as reconstituted milk powders, are subjected to quite high shear rates (between the palate and tongue). Many fluids exhibit turbulent flow when subjected to shear rates of this order. Thus, sensory evaluation of low viscosity fluids could well be based on shearing stresses developed in turbulent flow. The turbulence is reduced when saliva is added but in low viscosity fluids the effect is not completely removed. Such fluids would seem more viscous in the mouth than they actually are. There is a suggestion that because minimal saliva is secreted during the swallowing of low viscosity fluids there is a better correlation with objective measurements than there might otherwise be, turbulent flow affecting both measurements (Parkinson and Sherman 1971).

2.3 Relationships between Objective and Subjective Measurements

The relationships between objective measurements and subjective assessments are, as yet, imperfectly understood. This may be due, in part, to important differences between numercial aspects of objective measurements and descriptive aspects of sensory evaluation. The association between objective and subjective measurements is a 'covariation' caused by underlying common effects rather than a direct relationship between two different types of measurements of the same property (Kramer and Szczesniak 1973).

Methods for studying the relationships between objective and subjective variables include correlation techniques. A high correlation coefficient (*r* value) is required before a single instrumental measurement can be used with confidence instead of the sensory assessment. However, in pragmatic terms, an instrumental measurement with a lower correlation coefficient may be an adequate indicator of the underlying changes occurring in samples if the relative cost of an instrumental measurement is much lower than the cost of a sensory panel. Kramer (1976) believed that 0.94 rather than 1.0 indicated practically perfect agreement between any objective and subjective test. Kramer (1976) stated that a correlation coefficient of 0.9 or better was an excellent indicator of the quality attribute. A coefficient of 0.8 to 0.9 was considered satisfactory although a higher correlation coefficient was desirable. If the coefficient failed to reach 0.8, then the method was considered unsatisfactory and that sensory quality could not be predicted with sufficient accuracy by the proposed objective test.

Thus, the actual value of the correlation coefficient is important, the fact that it is statistically significant may not be of great value. When a large number of data points are involved in a correlation, a high correlation is not required before the coefficient becomes statistically significant. This was true of the present study in which approximately a thousand data points (when all the sensory estimates were used) were involved in each correlation.

Steel and Torrie (1960) have also emphasised the distinction between significance and meaningfulness in correlation coefficients. Small values of r may be significant but the correlation may be quite useless.

Statistical analysis makes possible the prediction of one variable from values of the other variables, within certain confidence limits. Partial regression coefficients indicate the relative importance of each of the objective methods while the coefficient of determination indicates the extent to which the selected methods predict the sensory attribute (Kramer 1972). While instrumental measurements are aimed at replacing sensory evaluation, it must be remembered that statistical procedures, like multiple regression, are descriptive rather than predictive. Therefore, predictions from instrumental data to sensory properties demand that such procedures be supplemented with a thorough knowledge of the underlying mechanisms (Kramer and Szczesniak 1973).

In the present study sensory estimates of colour and texture were made by a trained panel on one hundred and twelve milk powders throughout a nine month dairying season. The sensory data were then studied in relation to instrumental measurements of colour and texture made on the same powders.

3. COMPARISON OF SENSORY AND OBJECTIVE MEASUREMENTS FOR PARTICLE SIZE

Sensory assessments of particle size were studied in relation to measurements of particle size distribution (see Methods 4.2.2.) made on the same powders. There were two physically distinct groups of powders evaluated for their particle size distribution, non-agglomerated powders and agglomerated powders. Because different sized sieves were used to measure the particle size distributions of these two groups, data from each group were studied first as a separate entity. Sensory scores for each of these two groups of powders were correlated with instrumental measurements made on the same powders.

3.1 Relationships between Sieve Analysis Data and Sensory Estimates of Particle Size in the Powders

From each sieve analysis, six measurements were obtained. There was a measurement for the powder retained on each of the five sieves and in the pan (all expressed as a percentage). To begin with, the sensory data were correlated, in turn, with the data from each of these measurements (see Table 19).

Table 19: Results of direct correlation between the sensory estimates of particle size and data from individual sieve measurements made on both agglomerated and non-agglomerated whole milk powders.

Powder Type		Correlation Coefficient r
Non-agglomerated:	180 micron sieve	0.800 ***
	125 micron sieve	0.833 ***
	90 micron sieve	0.066 NS
	64 micron sieve	-0.790 ***
	45 micron sieve	-0.801 ***
	Pan	-0.765 ***
Agglomerated:	500 micron sieve	0.272 ***
	250 micron sieve	0.671 ***
	125 micron sieve	0.236 ***
	90 micron sieve	-0.592 ***
	64 micron sieve	-0.622 ***
	Pan	-0.456 ***

Data from the non-agglomerated powders indicated a highly significant (at the 0.1% level) correlation between the percentage powder retained on the first (180 micron) and second (125 micron) sieves and the sensory estimate of particle size. This was a direct relationship, as more powder was retained on either of these sieves, the sensory estimates of particle size in the powder increased. The correlation with data for the percentage powder retained on the third (90 micron) sieve indicated no significant relationship with the sensory estimate of particle size. However, correlations with the percentage powder retained on the fourth (64 micron) sieve, fifth (45 micron) sieve and in the pan correlated significantly (at the 0.1% level) with the sensory estimates. The correlations with data from these last three measurements indicated an inverse relationship. As these values became higher, the panel perceived the powder as finer in particle size.

In the agglomerated powder, correlation of the sensory data with data from each of the six sieve analysis measurements, indicated a similar pattern to that shown by the non-agglomerated powder (see Table 19). However, the correlation coefficients were not as high, indicating that relationships were not as close as those with the non-agglomerated powders. Again the data from the first (500 micron) and second (250 micron) sieves correlated significantly with the sensory data but the coefficients were not as high as those for similar data in the non-agglomerated powders. For this group of powders, data from the third sieve did correlate significantly with the sensory data but the correlation coefficient was still the lowest for these measurements. Once more, correlations with data from the fourth (90 micron) sieve, fifth (64 micron) sieve and from the pan were significant. An inverse relationship was indicated again, as the percentage powder retained increased the sensory estimate decreased.

Correlations made with both sets of data indicated significant correlations with the two coarsest fractions and with the three finest fractions of each powder. In both cases, the correlation coefficient for the middle fraction (third sieve) was the lowest for all six measurements made. The very coarse particles and the very fine particles in milk powder appear to be the key to the evaluation of its particle size and could hold the key to consumer acceptance of this attribute in the marketplace. Baldwin (1977) believed that the influence of the larger particles, in particular, was due in part to the resolution of the human eye (about 0.2 mm). While this will undoubtedly influence the perception of particle size, it is interesting to note that the third sieve for the non-agglomerated and agglomerated powders (which showed a low correlation in both sets of data) was not the same mesh size for these two groups of powder. In the non-agglomerated powders it was a 90 micron sieve which showed a highly significant correlation with sensory estimates in the agglomerated powders. In the agglomerated powder, it was a 125 micron sieve which similarly showed a highly significant correlation with sensory estimates for the non-agglomerated powders. Although the perception of particle size must be influenced by the resolution of the eye, it would also appear to be influenced by the range of particle size presented in each powder. McBride (1980) has shown that the response of a panelist is affected by the range of intensity presented to him or her. This kind of range effect appeared to occur in the assessment of particle size in whole milk powders.

3.2 Relationships between Indices of Particle Size Distribution and Sensory Estimates of Particle Size in Whole Milk Powders

The direct correlation of appropriate sensory data with data from the individual sieve measurements gave some indication of what affected the sensory estimates of particle size. However, dividing the data into two groups in this fashion gave no overall measure of the total data nor did it give a very satisfactory measure of the agglomerated powders, in particular. The values determined by a sieve analysis represent only a few isolated points on the particle size curve. Because of this, it is usual to plot the individual values in the form of a graph. Joined to form a smooth curve, this graph depicts the relationship of particle size throughout the entire range, giving an overall size curve. Cumulative undersize curves are commonly used which indicate the sum of the weight percent of all fractions from zero to the size concerned.

For such a graph, the linear scale offers the greatest simplicity. However, this scale suffers the disadvantage that the region representing the finest particles is compressed and cannot be accurately read. Because of this, a logarithmic scale is usually used for particle size along the Y axis and a linear scale along the X axis for percentage undersize (Lauer 1966). A logarithmic transformation was applied to the data from each sieve (expressed as grams retained on each sieve). Following this, a probit transformation (Paradine and Rivett 1960) which calculated maximum likelihoods was applied to the cumulative weight percentage undersize. A linear least squares regression line was then fitted to the data from each sieve analysis. From the regression equation, the median particle size (M') and slope (σg) were calculated and the mean surface volume particle size (d_{sv}) derived from the equation (Irani and Callis 1963):

$$\ln d_{sv} = \ln M' - 0.5 \ln^2 \sigma g$$

Sensory estimates of particle size from all the powders were correlated with each of these calculated values in turn. The correlation coefficients (shown in Table 20) indicated that there were highly significant correlations between the sensory data and both the median particle size and the mean surface volume of the particles. Of the two measurements, the mean surface volume gave a very slightly higher *r* value. The correlation between the sensory estimate for the particle size and the standard deviation of the particle size distribution (σg) was not significant. The correlation coefficients for both median particle size and mean surface volume of the particles were high. Either of these measurements could be used to indicate changes in the particle size of powders perceptible to the panelists.

Table 20: Results of direct correlations between sensory estimates of particle size and calculated indices of particle size distribution in whole milk powders.

	Correlation Coefficient *r*
Median particle size (M')	0.888 ***
Slope of regression line (σg)	0.052 NS
Mean surface volume (d_{sv})	0.890 ***

Multiple regression techniques were then used to find the combination of these calculated indices which best described the perception of particle size. In carrying out these regression analyses it was found that two of these calculated indices, median particle size and mean surface volume, were very highly correlated (r = 0.992). If both sets of data were included in the regression equation, the coefficients of the equation could no longer be treated as partial derivatives. Because of this, both sets of data were not included in the same equation. The sensory data for particle size were regressed first on data for median particle size and the slope of the regression line, then on data for mean surface volume and the slope of the regression line. The equation which best described sensory estimates of particle size in terms of these calculated indices of particle size distribution was as follows:

$$\text{Particle Size} = 0.58 + 24.66^{***} d_{sv} + 1.95 \sigma g$$
(Sensory Estimate)

where d_{sv} = Mean surface volume
σg = Slope of regression line.

Despite the inclusion of these two measurements, the equation was not much closer (r^2 = 0.806) in its explanation of panel estimates than the single calculated values of median particle size or mean surface volume. One of the calculated values, such as the mean surface volume, would be an adequate measure of this sensory property without resorting to the more complex regression equation.

4. COMPARISON OF SENSORY AND OBJECTIVE MEASUREMENTS FOR FREE-FLOWING PROPERTIES IN WHOLE MILK POWDERS

Traditional objective measurements of free-flowing properties in whole milk powders include tests such as the angle of repose and the flow rate through a funnel. Although none of these tests were used in the present study, it was of interest to see whether the sensory estimates of free-flowing properties related to measurements of particle size which had been made. Because of the different way the agglomerated and non-agglomerated powders had been treated in the sieve analyses, data from the agglomerated powders and data from the non-agglomerated powders were studied as two separate entities.

4.1 Relationships between Sieve Analysis Data and Sensory Estimates of Free-Flowing Properties in Whole Milk Powders

Sensory estimates for free-flowing properties in the powder were correlated directly with data from each of the six measurements made in the sieve analyses (see Methods 4.2.2.) The results of these direct correlations are shown in Table 21.

Table 21: Results of the direct correlations between sensory estimates of free-flowing properties in whole milk powders and data from individual sieve measurements made on both agglomerated and non-agglomerated powders.

Powder Type		Correlation Coefficient r
Non-agglomerated:	180 micron sieve	0.743 ***
	125 micron sieve	0.690 ***
	90 micron sieve	0.143 **
	64 micron sieve	-0.641 ***
	45 micron sieve	-0.751 ***
	Pan	-0.733 ***
Agglomerated:	500 micron sieve	0.382 ***
	250 micron sieve	0.435 ***
	125 micron sieve	0.118 **
	90 micron sieve	-0.422 ***
	64 micron sieve	-0.426 ***
	Pan	-0.242 ***

The correlation coefficients for data from these sensory estimates of free-flowing properties showed similar trends to the correlations between sensory estimates of particle size and the same objective measurements (see Table 20). As in the particle size data, the highest correlations were between the sensory estimates and the two coarsest and three finest fractions in each powder. The correlation with the middle fraction (third sieve) was significant in these data but was the lowest for all these measurements. The very coarse particles and the very fine particles appeared to have the greatest influence on the perception of free-flowing properties.

Baldwin (1977) concluded that large particles were required in a powder to impart granular, free-flowing properties. There was a direct relationship between the amount of powder retained on the first two sieves (the two coarsest fractions) and the perceived free-flowing properties of the powder. As the quantity retained on the sieve increased, so did the sensory score. However, as in the data for sensory estimates of particle size, the size of the fractions varied depending on the type of powder. The third sieve (which showed the lowest correlations with sensory estimates of free-flowing properties) was a different mesh size in each group. In the non-agglomerated powders, it was a 90 micron sieve, data from which showed a highly significant correlation with sensory estimates in the agglomerated powders. In the agglomerated powders it was a 125 micron sieve, data from which showed a highly significant correlation with sensory estimates for the non-agglomerated powders. The range of particle size presented to the panelist appeared to influence the judgement of free-flowing properties in the powder.

None of these correlation coefficients were as high as those for sensory estimates of particle size. This suggested that other factors involved in the sensory assessment of free-flowing properties were not accounted for in measurements of size distribution alone. The quantity of powder retained on the second sieve (125 micron and 250 micron sieves for non-agglomerated and agglomerated powders respectively) was the best single indicator of sensory estimates of particle size. These instrumental data remained the best indicator of particle size in the evaluation of agglomerated powders but in the evaluation of non-agglomerated powders, instrumental data from the fifth (45 micron) sieve was a better indicator. Thus, in the non-agglomerated powders, this very fine fraction was the key to the panelist's perception of free-flowing properties.

4.2 Relationships between Indices of Particle Size Distribution and Sensory Estimates of Free-Flowing Properties in Whole Milk Powders

Sensory estimates of free-flowing properties were then correlated with calculated values of median particle size, slope of the regression line (σg) and mean surface volume (d_{SV}).

Table 22: Results of direct correlations between sensory estimates of free-flowing properties and calculated indices of particle size distribution in whole milk powders.

	Correlation Coefficient *r*
Median particle size (M')	0.717 ***
Slope of regression line (σg)	0.254 ***
Mean surface volume (d_{SV})	0.691 ***

The results of these correlations (see Table 22) showed highly significant correlations (at the 0.1% level) between the sensory estimates for free-flowing properties and both the median particle size and the mean surface volume (d_{SV}). Of the two measurements, the median particle size gave the slightly higher correlation coefficient. In these data, the correlation between the sensory data and the slope of the regression line (σg) was also significant at the 0.1% level whereas they were not significantly correlated with sensory estimates of particle size. The correlation coefficients showed that although calculated indices of particle size distribution were important, other factors were involved in the sensory perception of free-flowing properties.

Analysis of the sensory data for free-flowing properties showed that although particle size was related to the sensory score, another factor was involved. Amongst the agglomerated powders, the lecithinated powders were seen by the panel as less free-flowing (more sticky) than non-lecithinated agglomerated powders. It was believed that this could be one reason why the sensory score did not correlate more closely with measures of particle size distribtuion. To illustrate this, a computer file was made in which agglomerated non-lecithinated powders were given a score of 4, agglomerated lecithinated powders a score of 3 and non-agglomerated powders a score of 2. Thus, the powders were arbitrarily scored such that the most free-flowing powders had the highest score and the least free-flowing the lowest scores. The scores of 4, 3 and 2 were chosen because of difficulties in the statistic-cal analysis when the more obvious scores of 3, 2 and 1 were used (these latter scores caused the matrix to singu-late). The sensory estimates for free-flowing properties were then correlated with these arbitrary data. The correlation coefficient (r = 0.700) for these two sets of data was highly significant (at the 0.1% level), although again it did not explain sensory estimates of free-flowingness precisely. This correlation did suggest that more was involved in the sensory estimation of free-flowing properties than those indices which described the particle size distribution alone.

Multiple regression techniques were again used with these data. Sensory estimates for free-flowing properties were regressed on data from the calculated indices of the particle size distribution (median particle size, slope of the regression line and mean surface volume) and on to the data from the arbitrary scores for powder type. The equation which best described the sensory estimates of free-flowing properties in milk powders ($r^2 = 0.679$) was found to be as follows:

$$\text{Free-flowingness (Sensory Estimates)} = -4.56^{***} + 7.73^{***}\sigma g + 8.73^{***} d_{sv} + 9.48^{***}T$$

where σg = Slope of regression line

d_{sv} = Mean surface volume

T = Powder type (arbitrary score)

This equation included the standard deviation of the particle size distribution (σg), the mean surface volume (d_{sv}) and the arbitrary scores for powder type. The regression coefficient from this equation indicated that a significant portion of the sensory estimates was explained by these three sets of data. The regression coefficient was still not high enough for this equation to be considered an exact expression of the panel's perception of free-flowing properties in milk powders. None of the expressions from these correlations, single and multiple could be considered close expressions of the sensory estimation of free-flowing properties in milk powders. Median particle size could be used as a single indicator of these changes, provided it was understood that other unexplained factors may affect sensory perception of free-flowing properties in whole milk powders.

5. COMPARISON OF SENSORY AND OBJECTIVE MEASUREMENTS FOR COLOUR

Beta-carotene has been implicated as the major natural colorant responsible for the colour of milk and milk powders and sensory estimates were studied in relation to the total colour of the powder, expressed as μg β-carotene (see Methods 4.1.4). The total colour measurements were expressed both as μg β-carotene/g fat and as μg β-carotene/g powder. The sensory data were also studied in relation to reflectance measurements made on the powders using a Hunterlab D25 colorimeter (see Methods 4.1.2). The reflectance measurements included measurements of the L, a and b values for each powder together with the 'Yellowness Index' (calculated as 125(X% - Z%)/Y) and 'hue' (calculated as arctan a/b). All these Hunterlab reflectance measurements were made with a white background similar to that used by the panel for their evaluation.

5.1 Relationships between Total Colour and Sensory Estimates of Colour in the Powders

Sensory estimates of colour were correlated directly with data from the total colour measurements. The results of these single correlations were:

	Correlation Coefficient r
Total Colour (μg β-carotene/g fat)	0.188 ***
Total Colour (μg β-carotene/g powder)	0.265 ***

The correlation coefficient for the sensory data and the total colour (expressed as μg β-carotene/g fat) was significant but the coefficient was not high (r = 0.188). As mentioned previously, because a large number of data points was involved in these correlations, a high correlation was not required before the coefficient became statistically significant. The correlation of sensory data with the total colour (μg β-carotene/g powder) data was slightly higher (r = 0.265). However, although the correlation coefficients for both sets of data were significant (at the 0.1% level) they were not high enough to indicate a close relationship with the sensory data. Interestingly, the monthly means for the sensory data and the data from both total colour measurements showed remarkably similar seasonal patterns (see Table 23).

Table 23: Monthly means for total colour measurements and sensory estimates of colour made on whole milk powders

	MONTH								
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Total Colour (μg β-carotene /g fat)	16.0	13.9	13.3	12.0	9.0	9.5	8.8	8.3	9.9
Total Colour (μg β-carotene /g powder)	4.5	3.9	3.8	3.4	2.5	2.7	2.5	2.3	2.8
Sensory Estimates	5.8	5.0	4.7	4.5	4.7	4.5	4.3	4.6	5.2

The low correlation between sensory and total colour data might have been predicted since the total colour (expressed as β-carotene) of a milk powder is independent of the powder's physical characteristics. Powders might have the same carotene content but differ markedly from each other in terms of physical structure, in particular their particle size. This physical structure of the powder has a considerable effect on the perceived colour. The larger the particle size, the brighter the powder colour appears. This aspect of perceived colour is not accounted for in the measurements for total colour.

Carotenoid pigments are concentrated in the milkfat of a milk powder. When total colour is calculated as μg β-carotene/g powder, this does allow for the effect that differing fat content in the powders has on the perceived colour. Therefore, the correlation of the sensory data with total colour data (expressed as μg β-carotene/g powder) might be expected to be higher than with the β-carotene data (expressed as μg/g fat). This is certainly true for the data reported here. However, the effect which the physical structure of the powder has on perceived colour is not accounted for in either set of data. Hence, neither coefficient indicates a close relationship with perceived colour.

The effect that particle structure has on perceived colour can be shown using multiple regression techniques. The sensory colour data were regressed on data from the β-carotene measurements and on to calculated indices of particle size distribution. These indices (described fully earlier) were calculated from sieve analysis measurements made on the same powders. They are a means of representing the particle size distribution of a powder in one or two measurements. The following equation ($r^2 = 0.667$) was found to best describe the sensory estimates of colour in terms of these measurements.

$$\text{Colour (Sensory Estimate)} = -2.26^{*} + 9.52^{***}TC + 24.08^{***}d_{sv} + 4.00^{***}\sigma g$$

where TC = Total colour (mg β-carotene/g powder)
d_{sv} = Surface mean volume
σg = Slope of regression line.

This equation, which included measurements of particle size, was considerably closer in describing sensory estimates of colour than the measurements of total colour had been alone, indicating the significant part that particle structure played in the perception of colour.

5.2 Relationships between Reflectance Measurements and Sensory Estimates of Powder Colour

The sensory data for colour were also correlated with data from the reflectance measurements made using the Hunterlab colorimeter. The Hunterlab *L,a,b* values measure the three dimensions which make up perceived colour. The *L* value indicates the whiteness or brightness of an object, the *a* value the red-green component of colour and the *b* value the blue-yellow component of colour. Because the Hunterlab *L, a, b* scale approximates perceived colour, it was hoped that the relationships between the sensory data and these instrumental data would prove closer than those with the total colour measurements. To begin with, sensory data were correlated with data from each of the reflectance measurements (see Table 24).

Table 24: Results of direct correlations between the sensory estimates of colour in whole milk powders and Hunterlab reflectance measurements.

	Correlation Coefficient *r*
Hunterlab *L* value	-0.529 ***
Hunterlab *a* value	-0.358 ***
Hunterlab *b* value	0.770 ***
Hunterlab 'Yellowness Index'	0.802 ***
Hunterlab 'hue' value	0.446 ***

Correlation coefficients for the L and a value data (r = -0.529 and r = -.358 respectively) indicated an inverse relationship between these values and the perceived colour. As powders became whiter and tended towards green they were scored lower. Neither measurement was a close approximation of the total change in colour. Correlation of the sensory data with the b value data and then with the 'Yellowness Index'data (r = 0.770 and r = 0.802 respectively) showed that as these values increased the sensory score increased also. The colour of whole milk powders ranges from cream through to pale yellow and these particular measurements were expected to be good indicators of colour changes in the powders. These measurements were made directly on milk powder samples and therefore took into account the effect physical structure had on colour, which the β-carotene measurements had failed to do. Calculated values for 'hue' also correlated significantly with the sensory data (r = 0.446) but not as highly as the b value data or the Yellowness Index data. 'Hue' was calculated from both a and b values. Since the a value data were not highly correlated with the sensory data, this may have accounted for the lower correlation coefficient of the sensory data with the calculated 'hue' values.

Multiple regression techniques were then used to find the combination of measurements which best described perceived colour. In carrying out these regression analyses, it was found that the Hunterlab b values and the Hunterlab Yellowness Index were very closely correlated (r = 0.992). As in the particle size data, two regression analyses were made. In one regression analysis, the sensory data were regressed on all the Hunterlab data excluding the Hunterlab Yellowness Index data and in the other analysis the sensory data were regressed on all Hunterlab data excluding the b value data. The equation which best described the sensory estimates of colour in terms of the reflectance measurements made using the Hunterlab colorimeter was as follows:

$$\underset{\text{(Sensory Estimate)}}{\text{Colour}} = 7.35^{***} + 20.59^{***}YI - 8.52^{***}L + 2.42^{*}a$$

where YI = Hunterlab 'Yellowness Index'
L = Hunterlab L value
a = Hunterlab a value

This equation included data from three measurements, the Hunterlab 'Yellowness Index', Hunterlab L value and Hunterlab a value. The r^2 value ($r^2 = 0.717$) indicates that a significant portion of the sensory estimates of colour was explained by these instrumental measurements. The Hunterlab colorimeter measurements were made directly on the whole milk powders and should have taken into account the effect particle size had on colour.

The sensory data were then regressed on reflectance data and data from the calculated indices describing the particle size distribution (as was done with the total colour data). The following equation ($r^2 = 0.761$) best described the sensory estimates of colour:

$$\underset{\text{(Sensory Estimate)}}{\text{Colour}} = 4.75^{***} + 11.70^{***}YI - 4.72^{***}L + 5.31^{***}a + 6.53^{***}d_{sv}$$

where YI = Hunterlab 'Yellowness Index'
L = Hunterlab L value
a = Hunterlab a value
d_{sv} = Surface mean volume

This was a closer expression of the sensory estimates for colour than any combination of reflectance measurements had been. Both sensory and reflectance measurements were made on the same powder samples presented in exactly the same way. However, the mean surface volume (d_{sv}) measurements related to some aspect of perceived colour which the reflectance measurements alone were unable to measure.

5.3 Discussion

The results of these correlations and multiple regression techniques reinforce the work of previous researchers in the field of colour evaluation. The instrumental measurements do not exactly follow the sensory estimates of colour. There are obviously some factors which are not accounted for by the instrumental measurements which are important in the perception of colour by the panelists.

Little (1973) pointed out that the visual process is a synthetic one, colour being perceived in its totality by the subject. This worker considered instruments to be analytical tools only, not 'electronic eyes'. At best they could measure dimensions important in the consumer's perception of colour. The instrument is useful only to the degree that it is imitative of what the consumer perceives. The reasons for the instrument's deviation from what is perceived may be various. One of the commonest is that an instrument may be more accurate than a panelist in identifying small differences between samples. In general this was found to occur with all the instrumental measurements made in the present study.

When analysis of the data was carried out to show the effect that seasonal changes had on the colour of milk powders, it was found that month effects were highly significant for all instrumental measurements. Relatively small changes occurring between the months were significant. However, analysis of the sensory data showed that only the gross changes in colour occurring at the beginning and the very end of the dairying season were seen as significant by the panel. For example, the monthly means for the Hunterlab 'Yellowness Index' (which had the highest correlation coefficient with the sensory data) indicated that the first five months were significantly different from each other but that the last four months did not differ significantly. In the sensory data, the first two months and the last month only differed significantly from the rest of the season. Changes through to the mid-season period were measured more accurately by the Hunterlab 'Yellowness Index' measurements than by the sensory panel. However, this instrumental measurement failed to differentiate late season powders which the panel perceived as being significantly more yellow (following the total colour trends shown in Table 23). From this, it appears that some of the correlation coefficients with the instrumental measurements may not have been higher because of the greater sensitivity of the instruments.

None of the instrumental measurements of colour offered a complete substitute for perceived colour in whole milk powder. However, the reflectance measurements were the best indicators of changes in the perceived colour of whole milk powders. Of these reflectance measurements, the Hunterlab 'Yellowness Index' offers the best single measure of perceived colour. This measurement does not change in exactly the same fashion as the sensory scores but would be an adequate measure of the underlying changes in colour. Colour tolerance limits could be set (the amount of change required in the instrumental measurement before a significant change in the perceived colour of whole milk powders occurs) to make this instrumental measurement more imitative in its measurement of perceived colour.

6. COMPARISON OF SENSORY AND OBJECTIVE MEASUREMENTS FOR VISCOSITY

A number of measurements of viscosity were made in the reconstituted milks. It was hoped that these measurements would relate to the sensory perception of viscosity by the panel. Instrumental measurements were made using a capillary viscometer (see Methods 4.3.2) this being a measure of absolute viscosity of the milks. Measurements of viscosity were also made using a Ferranti-Shirley cone and plate viscometer (see Methods 4.3.3) at nine different shear rates. In the evaluation of viscosity, studies have suggested that the shear rate operating in the mouth during the assessment of fluids varies with the viscosity (Parkinson and Sherman 1971). Low viscosity fluids, such as reconstituted milk powders, are subjected to quite high shear rates between the palate and tongue. Because of this, it was hoped that the use of the Ferranti-Shirley viscometer might more nearly approximate the perception of viscosity in the mouth than the capillary viscometer.

6.1 Correlation of Sensory Estimates of Viscosity with Capillary Viscometer Measurements

Correlation of sensory data with data from measurements made using the capillary viscometer showed a statistically significant correlation (r = 0.248) at the 0.1% level. As the viscosity of the reconstituted milk increased, the sensory score increased. However, a close relationship between the sensory estimates of viscosity and the instrumental data was not indicated. Since this was an absolute measurement of viscosity, it had not been expected to relate closely with sensory perception of viscosity which involves quite high shear rates between the tongue and hard palate.

6.2 Correlation of Sensory Estimates of Viscosity with Ferranti-Shirley Viscometer Measurements

Sensory estimates for viscosity were correlated with data from each of the nine measurements made using the Ferranti-Shirely cone and plate viscometer (see Table 25).

Table 25: Results of direct correlations between sensory estimates of viscosity in reconstituted samples and instrumental measurements of viscosity made using a Ferranti-Shirley cone and plate viscometer.

		Correlation Coefficient r
Ferranti-Shirley viscometer:	$500s^{-1}$	-0.139 ***
	$1000s^{-1}$	0.023 NS
	$1500s^{-1}$	0.033 NS
	$2000s^{-1}$	0.017 NS
	$2500s^{-1}$	0.026 NS
	$5000s^{-1}$	0.036 NS
	$10000s^{-1}$	0.125 ***
	$15000s^{-1}$	0.160 ***
	$18000s^{-1}$	0.078 **

The sensory data were found to correlate significantly with measurements made using the Ferranti-Shirley viscometer at a shear rate of 500s-1. These data very strangely indicate an inverse relationship, as the instrumental value increased the sensory score for viscosity decreased. At these very low shear rates, data from the Ferranti-Shirley viscometer were not very accurate. The errors in the readings were almost as great as the readings themselves. This significant correlation coefficient points to some of the dangers when correlations are being made with a large number of data points. It is possible for data to become significantly correlated even when the validity of the data is doubtful.

Of the remaining measurements made using the Ferranti-Shirley cone and plate viscometer, only correlations of the sensory estimates with measurements made at shear rates of 10 000 s^{-1}, 15 $000s^{-1}$ and 18 $000s^{-1}$ showed statistically significant correlations. The correlation coefficients for all three of these instrumental measurements indicated direct relationships between the sensory estimates and the instrumental measurements. As the instrumentally measured viscosity increased, the sensory score for viscosity increased. Measurements made at 15 000s^{-1} gave the highest single correlation with the sensory data.

It had been hoped that the Ferranti-Shirley measurements would be a good approximation of the sensory data because of the reportedly high shear rates acting in the mouth during the evaluation of low viscosity fluids. However, none of the correlation coefficients for these instrumental data was very high. Thus, the relationship between the instrumental measurements and the sensory estimates of viscosity was not a close one for any of these sets of data. It is interesting to note that the highest correlations between sensory and instrumental data were obtained at high shear rates. It appears that at these high shear rates, the instrument began to approach the process occurring in the mouth during the evaluation of viscosity. None of these single correlation coefficients approached a level at which one could consider them as a single indicator of change in samples. There were obviously many other unexplained factors which had a sigificant effect on the perception of viscosity in reconstituted milks.

The use of multiple regression techniques was explored with the viscosity data. As in the reflectance and particle size data, it was found that the readings made using both the Ferranti-Shirley viscometer and the capillary viscometer were all significantly correlated with each other. Consequently, when several sets of these data were included in the regression equation, the coefficients of the equation could no longer be treated as partial derivatives. Because of this, the use of regression techniques to find the best expression of sensory estimates of viscosity was considered inappropriate.

6.3 Discussion

From these correlations, it appeared that the panel's perception of viscosity in the reconstituted milks was not at all closely related to viscosity as measured by the instruments. Machines cannot appreciate texture as a human being does, they can only measure relevant physical characteristics which are implicated in the perception of texture. People are endowed with physiological and psychic equipment which makes it possible to 'know' nuances of texture. Difficulties arise only when they wish to describe these forces further either in qualitative or quantitative terms. Often the description of a degree of some textural mouthfeel reduces to a communication problem, the effectiveness of an adjectival description transmitted from one person to another (Corey 1970).

The present study reinforces these views. A relatively simple textural attribute, such as viscosity, might be expected to correlate significantly with measured viscosity. It is clear that there are major differences in what the panel termed 'viscosity' and the well-defined physical viscosity measured by the instrument. It is possible that sensory perception of viscosity related to such things as mouthfeel, the fat content of the reconstituted milks and the distribution of the fat globules. These factors might well give rise to a rich, 'thick' feel to the milk without changing its instrumentally measured viscosity. Because there were too many unknown factors in the sensory perception of viscosity, none of the instrumental measurements for viscosity could be considered as a substitute for the sensory estimates.

7. CONCLUSIONS

Correlations were made between sensory estimates of particle size and measurements of the particle size distribution. In both agglomerated and non-agglomerated powders the values from the second sieve (one of the coarser fractions) had the greatest influence on perception of particle size. In agglomerated and non-agglomerated powders, this fraction contained slightly different particle sizes and it appeared that the range of particle size in a powder influenced the judgement of the panelist. Sensory data were also correlated with calculated indices describing the particle size distribution. High correlations were found between sensory estimates of particle size and calculated values of median particle size ($r = 0.888$) and mean surface volume ($r = 0.890$). Multiple regression techniques were carried out with these data but the regression equation did not explain much more of the sensory estimates of particle size than the single correlations of changes in the particle size of whole milk powder likely to affect consumer acceptance.

Measurements made to describe the particle size distribution of the powders were also correlated with the sensory estimates of free-flowing properties in the powders. These correlations followed a similar pattern to those correlations made with the particle size data. The correlation coefficients were not as high as in the particle size data indicating that other factors influenced the perception of free-flowing properties. As in estimates of particle size, values from the second sieve (one of the coarser fractions) were important in the perception of free-flowing properties. It was the most important single value in perception of this attribute in agglomerated powders but in the non-agglomerated powders values from the fifth sieve (one of the finest fractions) were more important. Sensory estimates were again correlated with calculated indices of the particle size distribution. Of the three calculated indices, the median particle size gave the highest single correlation coefficient (r = 0.717). This was the highest single indicator of change for the agglomerated powders but the value from the fifth (45 micron) sieve was a better indicator of change in the non-agglomerated powders (r = -0.751). For these data, the regression equation (r^2 = 0.679) was a much closer expression of the panel's perception of free-flowing properties than the single measurements. This regression equation included calculated values for the slope of the regression line (σg), the mean surface volume (d_{sv}) and an arbitrary score for powder type.

Instrumental measurements of colour all showed statistically significant correlations with sensory estimates of colour for the same powders. Data from the Hunterlab D25 colorimeter gave the highest single correlations with sensory data. The Hunterlab 'Yellowness Index' gave the highest correlation coefficient with the sensory data and could be considered a satisfactory measure of sensory changes in the colour of milk powders. However, this measurement was still not an exact expression of perceived colour. It is possible that these two sets of data were not closer because of the greater accuracy of the instrument in determining small differences between samples. A multiple regression equation did not explain much more of the sensory estimates of colour than the single correlation coefficients had done.

Relationships were also sought between sensory estimates of viscosity in the reconstituted milks and the instrumental measurements of viscosity. Correlations between the instrumental measurements and sensory estimates of viscosity were not high. Measurements made with a capillary visco-meter gave the best correlation (r = 0.264) with sensory estimates of viscosity. This correlation coefficient, although statistically significant, was not high indicating that other unexplained factors influenced the sensory judgement of viscosity. These data showed that what the panel measured as 'viscosity' was in all probability composed of a number of factors related to mouthfeel, fat content etc., and not necessarily related to instrumentally measured viscosity. None of the instrumental measurements of viscosity could be considered as a direct substitute for the perceived viscosity of the reconstituted milks.

To summarise; the instrumental measurements generally did not relate closely to many of the sensory attributes. The Hunterlab 'Yellowness Index' and the mean surface volume of the particles were the only good indices of colour and particle size respectively. Because of this, data from these two measurements were used to study the effects of seasonal changes on the sensory properties of whole milk powders in addition to the sensory data.

CHAPTER VII

SEASONAL EFFECTS ON SENSORY PROPERTIES OF WHOLE MILK POWDERS

1. INTRODUCTION

The New Zealand's dairy industry relies upon this country's equable climate. The industry is based on the land's ability to produce pasture of sufficient quality to feed our dairy herds for approximately nine months of the year without the need for extra feeding out. Because the economics of the industry depend upon the cheap production of milk, the industry is a seasonal one, relying upon the growth of pasture from spring through to autumn to support the dairy herds.

Although New Zealand has a very moderate climate, pasture growth from spring through to autumn shows some distinct changes. There is a period of very fast growth during the spring, the so-called spring 'flush'. This is followed by a relatively stable mid-season period leading to a drying up of the pasture in the late summer. Then begins another period of growth during the early autumn before the winter sets in. As the pasture changes so does the milk and the products made from this milk. These changes lead to the so-called 'seasonal effects'.

One complicating factor is that it is difficult to distinguish between true climatic or seasonal effects and lactational effects. Cows are brought into lactation to synchronise with the pasture growth and Dolby (1969) observed that it is often difficult to distinguish between lactational changes and those due to seasonal changes in pasture or other conditions. However, especially when there are differences in the intensity of change between one season and another, the observed effects can be reasonably assumed to be seasonal effects only.

Seasonal changes in the colour of New Zealand milkfat are probably among the most obvious and have been studied by several workers. Overseas workers, such as Buma et al. (1977), have noted that milk produced from pasture fed cattle contains much higher levels of β-carotene, resulting in a more yellowish colour, than milk from stall fed cattle. Because dairy cows in New Zealand are substantially pasture fed, this results in milkfat which at certain times of the season contains a marked yellow colouration due to the presence of high concentrations of carotenoid pigments (Keen and Udy 1980). Workers, such as McDowell (1956), have shown that the carotene content of New Zealand milkfat decreases from a maximum in the early spring to a minimum in the late summer (February) with a subsequent increase through the autumn. McDowell (1956) found that this rise in the carotene content in the autumnal period was not observed in all seasons. Thus, it was assumed that this was a seasonal rather than a lactational effect. He believed that these seasonal differences in the carotene were due to the availability of carotene in the pasture. However, McGillivray (1956) found that available carotene was high throughout the season. This worker believed that the lower carotene content in the products resulted from decreased utilization of carotene from summer pastures rather than from a deficiency of carotene in the diet. It was thought that during the late summer period something interfered with the uptake of carotene.

Other seasonal changes in the milkfat have not been studied in such detail. Dolby (1969) stated that changes in the milkfat composition follow the changes in the pasture grasses. The lipid content of the grasses is high and unsaturated in the spring but changes to a lower and more saturated lipid content as the grass matures. McGillivray (1956) pointed out that over the seasonal period there was decreased uptake of pasture fats. Whether this resulted from a decreased utilization of fats and fat-soluble materials or from decreased levels of fat in the mature pasture was not known.

These seasonal changes in the pasture must be reflected in the milk and milk products. How these seasonal changes affect whole milk powder had not previously been studied. In particular, it was of interest to see how they affected the sensory properties of whole milk powders. Because whole milk powder is a fat-containing product, one would expect that seasonal changes seen in milkfat products would be reflected in this product also, if to a lesser degree. Thus, one object of the present study was to measure changes in the sensory properties of whole milk powders due to seasonal variation. To attain this objective, commercial samples of whole milk powder were tested by a trained sensory panel throughout the 1979/80 and 1980/81 dairying season.

2. BACKGROUND TO 1979/80 AND 1980/81 DAIRYING SEASONS

The New Zealand dairying season has a distinctive pattern with a spring 'flush', a relatively stable mid-season period and then a period of change in the autumn. However, the precise timing and intensity of these changes are dependent on the climatic changes in a particular season.

The 1979/80 and 1980/81 dairying seasons were quite different climatically. The spring of 1979 was very dry, delaying the effects of the spring 'flush'. There was then a relatively stable mid-season period followed by distinct changes in the final month of the season. Autumn came rather late in the season but when it came changes in the pasture were quite abrupt.

On the other hand, the spring of 1980 was both early and very wet. The effects of the spring 'flush' occurred relatively early. The differences in the early season effects were exacerbated by the timing of the first sample tested. During the 1979/80 season, powders were tested from the end of the first week in August onwards. During this season, the spring 'flush' came relatively late, so these samples showed the early season effects very clearly. In the second season, the first powders tested were processed in the third week of August. Thus, there was a difference of two weeks between the first powders tested in the 1979/80 season and the first powders tested in the 1980/81 season, a considerable period of time during this critical period. Not only was there a fortnight's difference in the time for the processing of the first whole milk powders but also the wet spring of 1980 made this lag time longer (in climatic terms). Consequently, the first powders tested in the second season were considerably later in the seasonal pattern than the corresponding powders in the first season.

The mid-season period for the 1980/81 dairying season was again relatively stable, as it had been in the previous season. However, the autumnal changes were not nearly as marked as they had been the season before. The late summer and autumn of the 1980/81 season were unusually wet, especially in the Waikato - a region where three of the participating factories are situated. There was much lusher pasture available throughout the late summer and early autumn than is usual. Thus, there were no marked changes in the pasture during this period, as would occur with the onset of autumn rains after a relatively dry summer.

There were significant seasonal effects in data from both seasons. Although the patterns for the two seasons were similar the degree of change was different, being a reflection of climatic differences between the two seasons.

3. METHODS

3.1 Sampling Methods

During the first season, samples of whole milk powder were obtained weekly from participating factories (as described in Methods 2.2) and evaluated by the panel. Instrumental measurements of colour, particle size and viscosity were also made on both powders and reconstituted milks. One hundred and twelve milk powder samples were tested during the 1979/80 season. Analysis of the data from these powders showed significant seasonal effects occurring, particularly during the early and late season periods. However, only a few factories were producing a limited number of powder specifications during these early and late season periods. Because of this, the data from these periods in the first season were very sparse and gave only a hint of possible trends.

During the second season, the aim was to study as many whole milk powders as possible from the beginning and end of the dairy season (where most change appeared to occur). The aim of this work was to determine whether significant seasonal changes did occur in the aroma, flavour and texture of whole milk powder during the first and last ten weeks of the dairy season. Participating factories were asked to supply samples of powders every second day from mid-August to late October and again from mid-February to the end of the season. During the mid-season period whole milk powders were tested once a fortnight, to give information supporting the data from the 1979/80 dairying season.

Two hundred and seventy eight powders were tested during the 1980/81 dairying season. One hundred and twenty two of these powders tested were processed during the first ten weeks of the season, one hundred and twenty two powders during the last ten weeks of the season. The major changes which occurred in samples tested during the 1979/80 season were in the sensory properties. Testing for these powders from the 1980/81 season concentrated on the sensory panel work. Powders were evaluated for characteristics of sweetness, butteriness, cooked/caramelised, lactone, oxidised, feedy, taint, age-related and vitaminized. The texture of the reconstituted milks was also evaluated for attributes of viscosity and astringency. A limited number of instrumental measurements for colour, particle size and viscosity were also made.

3.2 Method of Statistical Analysis

In setting up this study, it had been decided that a study of commercial whole milk powders would be of most value to the dairy industry. However, this posed considerable problems in the analysis of the data. Whole milk powder is not a commodity product in New Zealand. It is a product which is made to New Zealand Dairy Board non standard purchase orders. This means that whole milk powder is made only to meet specific customer orders. Powders are not made at steady intervals throughout the season. Consequently, there was no control over what was made at a certain point of the season, nor was there any control over when production started or ceased.

Because of all these limitations, the data from the two seasons were very scattered. This placed severe restrictions on the type of statistical analysis which could be used. To analyse all the data a DSIR Stats Pac program called Anovar (Applied Mathematics Division, DSIR, Palmerston North) was used. This program will carry out an analysis of variance on very scattered data for the main effects only. Although this program will analyse the data for the main effects, confounding still remains in these main effects. Thus, if there is a significant season or month effect this may be influenced by other effects if they too are significant. For example, if a certain powder is perceived as very intense for a certain characteristic, the month effect will be influenced by when these powders were tested. Consequently all significant effects had to be treated with some caution and with careful study of other factors which significantly affected the same attribute.

In analysing the sensory data, it was not possible to show how individual panelists were responding to different samples. However, in the analysis of each sensory attribute the panelist scores were used as the sub-samples so that all effects were clear of any panel variance. In addition, by using the panelist scores as sub-samples, it was possible to estimate the 'lack of fit' in the data. This 'lack of fit' figure in the analysis of variance table indicated whether an attribute was being fully explained by the three main effects of factory, specification and month. A significant 'lack of fit' figure could indicate interactions of these factors or unknown effects. More importantly in the sensory data, it indicated that the panelists' responses to samples were not the same, that there was a significant amount of panel variance occurring.

The Anovar program uses adjusted, rather than true, means to carry out tests of the means. Adjusted means have been reported throughout to show the changes occurring in the different attributes where

True Mean = Covariant Mean + Adjusted Mean

Although the adjusted means show the direction and significance of the changes occurring, they can become minus figures. It must be remembered that it is the relative change between means which is important, not the actual value of the mean.

There were some differences between the 1979/80 and 1980/81 seasons in the way in which the data from the 'other' characteristics were analysed. The 'other' categories were optional in the first season, each attribute had to be specified by the panelist and scored. It had not been thought that this was a very important aspect of the powders when this questionnaire was devised. However, contrary to expectation, these categories became very important, especially in defining the effects of certain processing changes. When the datawere collated from the 1979/80 season, it was found that the 'other' categories would divide readily into five categories - lactone, oxidised, feedy, taint and age-related. Because panelists had had to specify attributes, it was not felt justified to use unspecified characteristics as though they were a zero score. It was felt that to do that would give an unjustified number of degrees of freedom to the analysis which might make effects seem significant which were not. Instead, the total score for each attribute ineach powder was used for these analyses. Thus, the significance of effects was due to total variance in the powders. Because the total variance in the powders was used, the adjusted means in these particular analyses did sometimes exceed 10 (a 0-10 scale being in use by the sensory panel).

Before the 1980/81 season began, this 'other' category was re-defined by the panel. Because it had proved so important during the 1979/80 season, it was decided to define these characteristics more fully. Instead of leaving it to the panelists to specify the characteristic, there were now six defined characteristics of: lactone, oxidised, feedy, vitaminized, taint and age-related. The vitaminized characteristic was added in the second season since it was found during the 1979/80 season that powders containing added vitamins had characteristic aroma and flavour attributes. Because these characteristics were now defined, it was possible in the second season to analyse these data in the normal way, using panelist scores as the sub-samples. This resulted in adjusted means which were much smaller than those from the 1979/80 season by a power of ten (the number of panelists). So that comparisons between the two sets of means could be made more easily, all the adjusted means for the 'other' or 'additional' categories in the second season have been multiplied by ten.

4. SENSORY PROPERTIES UNAFFECTED BY SEASONAL CHANGES

Data from each of the sensory attributes evaluated during the 1979/80 season were analysed separately. While the colour of the powders was significantly affected by seasonal changes, it was found that the particle size and free-flowing properties of the powders were affected only by processing conditions. These two appearance characteristics were dependent on the physical structure of the powder (whether it was agglomerated or non-agglomerated) but not on climatic changes during the season. Indices of the particle size distribution were also analysed because of their close correlation with sensory perception of these attributes. Analysis of these data also failed to show any seasonal effects, processing variables being the key to changes in these measurements.

Seasonal effects were very important in the sweet, buttery and cooked/caramelised notes which made up the 'basic' profile of the whole milk powder aroma and flavour. However, seasonal effects were very weak or disappeared entirely in the 'other' or 'additional' categories of aroma and flavour. These categories were found to be crucial in evaluating the effects of vitamin and iron addition. Any slight seasonal effects in these attributes were overshadowed by processing effects.

5. SEASONAL EFFECTS ON PHYSICAL PROPERTIES OF MILK POWDERS

Analysis of the seasonal data showed strong seasonal effects occurring in whole milk powders, especially in the physical properties, such as the colour of the powders. These seasonal effects were also evidenced in the texture of the reconstituted milks, in the evaluation of viscosity and astringency.

5.1 Colour - Sensory Data

Analysis of sensory data for colour in whole milk powders (shown in Appendix 3) showed a highly significant seasonal effect. There was also a significant 'lack of fit' value which suggested that the panel response to this attribute was not uniform.

There was a sharp drop in the perceived colour at the beginning of the season, colour then stabilised mid-season, only to rise again in the last month of the season (see Table 26). These month effects will have been influenced by the powders tested during a particular month. However, the general trend follows the seasonal pattern in the colour of New Zealand milkfat reported by previous workers (McDowell 1956). Because the seasonal pattern shown by these data merely confirmed the observations of previous workers, only limited evaluations of colour were made on whole milk powders during the 1980/81 season. These evaluations were made to support the hypothesis of a relatively stable mid-season period. In fact, the monthly means (see Table 26) showed significant differences. These differences did not follow any obvious seasonal pattern and will have been due to the types of powders tested within each month (non-agglomerated powders were scored significantly lower than agglomerated powders).

Table 26: Monthly means from the 1979/80 and 1980/81 seasons for colour in whole milk powders

	MONTH									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
1979/80 Season	5.8	5.0	4.7	4.5	4.7	4.5	4.3	4.6	5.2	***
1980/81 Season	-	-	5.3	5.1	4.3	5.4	4.4	-	-	***

- indicates no powders testing during that month

Data from the 1979/80 season were split into data from vitaminized and non-vitaminized powder and re-analysed (see Appendix 3). The seasonal trend followed the same pattern in both vitaminized and non-vitaminized powders. This effect was not changed by the addition of vitamins, although the physical structure of the powder had a considerable effect on the perceived colour. The monthly means for the two groups of powders followed a very similar pattern to that shown by the complete 1979/80 seasonal data (see Table 26).

The spring of 1979 was very dry and the spring 'flush' came relatively late. This may have accentuated the seasonal effect of colour in whole milk powders. Total colour determinations made during this period of the 1979/80 dairying season indicated very much higher (19 μg β-carotene/g fat) total colour in the powders than in the spring of the 1980/81 season (15 μg β-carotene/g fat). Thus, although this seasonal pattern certainly exists, it may well be intensified by the climatic conditions of a particular season. Where colour is important to the consumer (in certain marketplaces yellow dairy products are considered inferior) it would seem that whole milk powder from the mid-season period should be marketed rather than powder from early or late season periods in which the colour may well be significantly 'yellower' and become objectionable to the consumer.

5.2 Colour - Hunterlab 'Yellowness Index'

Reflectance measurements made using the Hunterlab D25 colorimeter for the 'Yellowness Index' in whole milk powders were the closest instrumental approximation of perceived colour. Analysis of data from these measurements (see Appendix 3) showed a highly significant seasonal effect.

The monthly means (shown in Table 27) indicated a steady decrease in the 'Yellowness Index' as the season progressed. The most marked changes occurred in the first five months, these first months being significantly different from the rest of the season. Interestingly, the means for the first two months were not significantly different from each other, although very different from the rest of the season. Differences between powders from these first two months had been perceived by the panel as highly significant. The last four months of the season showed little change in the 'Yellowness Index'. There was no sign in these instrumental data of the significant increase in colour perceived by the panel in April (the final month of the season).

Table 27: Monthly means from the 1979/80 season for the Hunterlab 'Yellowness Index' in the whole milk powders

	MONTH									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
1979/80 Season	36.5	35.6	34.4	33.1	32.4	30.4	30.7	30.9	30.1	***

These instrumental data showed a similar seasonal trend to that of the sensory colour data. There was a general downward trend from a high point at the beginning of the season, the 'Yellowness Index' slowly decreasing to the end of the season. However, there were also differences between which months were seen as differing significantly from each other by the instrumental and sensory data. This suggested some reasons why the correlation coefficient between the two sets of data (r = 0.802) was not higher.

5.3 Viscosity

Analysis of data from the 1979/80 dairying season for viscosity showed a highly significant seasonal effect (see Appendix 5). The monthly means for these data (shown in Table 28) showed a slight rise in the perceived viscosity during September. Perceived viscosity appeared to increase through the last four months of the season but the greatest increase in this attribute occurred in April (the last month of the season). This significant seasonal effect occurred in both non-vitaminized and vitaminized powders being unaffected by the addition of vitamins and minerals. There was no significant specification effect in these data and it appeared that the perceived viscosity of the reconstituted milks was unaffected by the physical structure of the powder.

Table 28: Monthly means from the 1979/80 and 1980/81 seasons for viscosity in reconstituted milks

	MONTH									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
1979/80 Season	3.5	3.9	3.6	3.8	3.6	4.0	4.0	4.0	4.7	***
1980/81 Season	3.6	3.8	3.8	4.2	4.2	4.0	4.2	4.2	4.1	***

Viscosity data from the 1980/81 season showed a highly significant seasonal effect (see Appendix 6). Analysis of data from the early and late season periods failed to show any change occurring (see Appendix 6). The monthly means for the complete data from the 1980/81 season (shown in Table 28) suggest the reasons for this lack of early and late season effects. The perceived viscosity of the reconstituted milks was low at the beginning of the season. It rose in November and was relatively stable for the rest of the season dropping back slightly in the final month. Thus, the ten-week period at either end of the season was relatively stable.

The viscosity of the reconstituted milks was significantly lower during the early season period than later in the season. Viscosity appeared to change abruptly rather than gradually over several months. This change in the viscosity occurred in January of the 1979/80 season and in November of the 1980/81 season. The precise timing of this change will have been influenced by the climatic conditions of the individual seasons. There was no sign in the second season's data of the sharp increase in the perceived viscosity of the reconstituted milks which occurred in the last month of the 1979/80 dairying season. This marked change in viscosity appeared to be associated with the late season changes in the composition of the milk. These changes are quite dramatic during the late autumn, in particular changes in the protein:lactose ratio (often almost overnight). During the 1980/81 season, the participating factories made certain processing adjustments which may have helped to minimize the late season effects. These adjustments were not made during the 1979/80 dairying season. In addition, the second seaon was very different climatically, the late summer and early autumn were unusually wet and this may also have affected the seasonal trend.

5.4 Astringency

Analysis of data from the 1979/80 dariying season for astringency showed that in this textural attribute there was also a highly significant seasonal effect (see Appendix 7). Monthly means (shown in Table 29) showed a significant rise in astringency during the sixth month but the greatest rise in astringency occurred during the last month of the season, coinciding with the rise in the perceived viscosity of the reconstituted milks. Data from the vitaminized and non-vitaminized powders showed significant seasonal effects also. Trends shown by the monthly means for these powders were similar to those shown by the complete seasonal data. This effect was apparently a physical one which was not affected by the addition of vitamins and minerals.

Table 29: Monthly means from the 1979/80 and 1980/81 seasons for astringency in reconstituted milks.

	MONTH									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
1979/80 Season	2.6	3.6	3.2	3.5	2.9	4.0	3.2	3.0	4.8	***
1980/81 Season	2.9	3.2	3.5	3.9	3.5	3.9	3.8	3.8	3.5	***

Data from the 1980/81 dairy season again showed this highly significant seasonal effect in the astringency of the reconstituted milks (see Appendix 8). The monthly means for the 1980/81 dairying season (shown in Table 29) showed a steady increase in astringency during the first three months of the season, a sharp rise in November before dropping back only to rise again during the last months of the season. There was a slight drop again during the final month of the season. Analysis of data from the early and late seasonal periods showed a significant seasonal effect in the early season data only (see Appendix 8). The means for these data (see Table 30) indicated that astringency was significantly lower during the first month of production (end of August and beginning of September) than later in the season.

Table 30: Fortnightly means from the 1980/81 early season data for astringency in reconstituted milks

	MONTH					
	Late Aug	Early Sep	Late Sep	Early Oct	Late Oct	
1980/81 Season	2.7	2.9	3.2	3.3	3.4	**

The astringency of the reconstituted milks was plainly affected by seasonal changes. From the 1979/80 dairy season's data it appeared to be most strongly affected by end of season effects. Compositional changes do occur during this period of the season which could affect this attribute. The type of season may well affect this attribute. The autumn of the 1979/80 season was relatively late and changes in the milk occurred quite abruptly at the end of the season. In the 1980/81 season, the late summer and autumn periods were very wet and changes occurring may not have been as sudden or as distinct as in the previous season.

6. SEASONAL EFFECTS ON THE AROMA OF THE WHOLE MILK POWDERS

Analysis of sensory data for characteristics of the powder aroma showed that the most significant seasonal changes occurred in the 'basic' notes. These attributes of sweetness, butteriness and cooked/caramelised had been defined by the panel as making up the 'basic' or 'normal' profile of milk powder aroma. It was in these attributes, rather than in the 'other' or 'additional' categories of aroma in which seasonal effects caused most change.

6.1 Seasonal Effects on 'Basic' Aroma Characteristics in the Whole Milk Powders

The sweet, buttery and cooked/caramelised notes in the powder aroma showed highly significant seasonal effects (see Appendix 9). The seasonal effect was distinct for all three of these characteristics. The sweet, buttery and cooked/caramelised notes all increased in September, fell again during mid-season and rose again in April, the last month of the season. This seasonal pattern can be seen clearly in the monthly means for these three characteristics (see Table 31). These characteristics plainly follow a similar pattern and would appear to be related to each other.

Table 31: Monthly means from the 1979/80 and 1980/81 seasons for the sweet, buttery and cooked/caramelised notes in the aroma of whole milk powders

	MONTH									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
Sweetness:										
1979/80 Season	3.5	4.5	3.9	4.0	4.0	4.2	3.7	3.9	4.8	***
1980/81 Season	4.0	4.4	4.4	4.7	4.4	4.5	4.6	4.6	4.5	***
Butteriness:										
1979/80 Season	4.0	4.8	4.2	4.7	4.7	4.8	4.1	4.6	5.4	***
1980/81 Season	4.3	4.2	4.2	4.4	4.4	4.7	4.2	4.3	4.1	NS
Cooked/Caramelised:										
1979/80 Season	1.8	3.0	2.0	2.7	2.7	2.3	2.8	2.8	3.1	***
1980/81 Season	2.6	2.3	2.5	2.3	2.7	2.3	2.6	2.5	2.7	**

When data for the non-vitaminized and vitaminized powders were analysed separately the seasonal trend in the sweet, buttery and cooked/caramelised notes of the aroma was still found to be highly significant (at the 0.1% level). Thus, this seasonal trend was independent of the effects of vitamin and mineral addition.

Analysis of data for the sweet, buttery and cooked/caramelised notes in the aroma of the powder tested during the 1980/81 season showed (see Appendix 11) a significant seasonal effect in both the sweet and cooked/caramelised characteristics. The seasonal trends indicated for the second season (shown in Table 31) were not as dramatic as those occurring during the first season. This followed trends shown in the seasonal variation of the physical properties, such as the viscosity and astringency of the reconstituted milks. The two seasons were quite different climatically and this was reflected in the data. The 1979/80 season showed quite abrupt climatic changes which appear to have been reflected in the powders.

It is difficult to explain why the highly significant seasonal effect (at the 0.1% level) found in the buttery note of the aroma in the 1979/80 season disappeared completely in the 1980/81 seasonal data. The buttery note in the powder aroma followed many other aroma and flavour characteristics in the 1979/80 season, increasing sharply in September (when the spring 'flush' arrived) dropping back mid-season only to rise sharply in April with the onset of autumn. It should be noted that there was a significant 'lack of fit' figure for this attribute during the 1979/80 season, signifying that the panelists were not uniform in their response to this attribute and that there was significant panel variance. This 'lack of fit' ceased to be significant in the 1980/81 data, suggesting that the panel was much more uniform in its response to this attribute during the second season.

From the adjusted mean scores (see Table 31), it can be seen that the scores for the first three months of the 1980/81 season were somewhat similar and rather lower than scores for powders during the late season period. However, the early and late season periods were rather similar within themselves. This was evident in the analysis of data from these two periods (see Appendix 12). These analyses showed only a weak seasonal effect in the early season data for the sweet characteristic in the powder aroma. In the mean scores for the sweet note (shown in Table 32), the intensity of the note appears to be increasing from a low point late in August.

Table 32: Fortnightly means from 1980/81 early season data for the sweet note in the aroma of whole milk powders.

	FORTNIGHT				
	Late Aug	Early Sep	Late Sep	Early Oct	Late Oct
Sweetness	4.0	4.3	4.4	4.4	4.1 **

This follows trends in the mean scores from the 1979/80 season which indicated a low intensity of this attribute at the very beginning of the season. However, it is clear when the mean scores for August from the two seasons are compared, that the powders tested in August 1979 were processed in what was 'early spring' whereas those tested in August 1980 were processed in what was 'late spring'. Changes at this time in the season occur very quickly and it was quite clear that no powders tested in the early part of the second season showed the attributes of the very early powders from the 1979/80 season. The changes were much more gradual in the 1980/81 season, reflecting the very wet spring and even growth of the pasture.

6.2 Seasonal Effects on 'Other' Aroma Characteristics in the Whole Milk Powders

The 'lactone-like', 'oxidised' and 'age-related' notes in the powder aroma all indicated slight month effects in data from the 1979/80 season (see Appendix 13). Means for the different months (shown in Table 33) varied slightly but there was no clear seasonal pattern. When data from the 1979/80 season were split into data for vitaminized and non-vitaminized powders and re-analysed, these seasonal effects almost entirely disappeared (see Appendix 14). These significant seasonal effects disappeared entirely in data from the 1980/81 season for the same attributes (see Appendix 15). The adjusted means (see Table 33) showed an erratic pattern throughout the season. These attributes were typical of certain specification powders. The testing of a number of these powders in a certain month will have affected the adjusted monthly means (see 3.2 for explanation of statistical analyses). The seasonal effects found in the data from the 1979/80 season will undoubtedly have been influenced by these specification effects. The fact that these seasonal effects disappeared in the second season, casts some doubt upon their importance.

Table 33: Monthly means from the 1979/80 and 1980/81 seasons for the 'lactone-like', 'oxidised' and 'age-related' notes in the aroma of whole milk powders.

	MONTH									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
Lactone-like:										
1979/80 Season	2.6	3.2	0.7	2.0	2.7	1.2	3.1	3.6	1.5	**
1980/81 Season	5.8	5.7	6.8	7.3	4.0	9.0	5.6	4.6	5.4	NS
Oxidised:										
1979/80 Season	3.4	1.0	1.2	3.5	1.0	2.3	1.4	1.8	0.4	*
1980/81 Season	5.2	4.7	3.1	3.4	4.6	3.5	6.1	4.4	4.1	NS
Age-related:										
1979/80 Season	2.3	2.2	2.8	2.2	0.3	4.6	6.4	6.9	1.3	*
1980/81 Season	1.7	2.1	3.3	1.4	3.7	2.7	2.1	1.6	3.5	NS

Analysis of the data from the 1979/80 season for the 'taint' aroma characteristic indicated (see Appendix 13) a slight month effect. The means (see Table 34) varied but the effect was probably influenced by the type of powders being tested during a particular month. For example, a note associated with milk powders containing added vitamins was included in this 'taint' category during the first season. Thus, the testing of a relatively high number of vitaminized powders during a month would force the mean up, as happened in January and February.

Table 34: Monthly means from the 1979/80 and 1980/81 seasons for the 'taint' characteristic in the aroma of whole milk powders.

	MONTH									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
1979/80 Season	3.0	2.6	0.4	1.4	4.0	4.7	6.3	3.3	2.9	*
1980/81 Season	3.2	2.8	1.8	2.6	6.4	5.2	3.5	3.6	3.0	*

When data from non-vitaminized and vitaminized powders were analysed separately (see Appendix 14) it was found that this seasonal effect occurred in vitaminized powders only. The monthly means (shown in Table 35) for these two groups show a rather erratic pattern, no clear trend being visible. This suggested that the seasonal effect found in the complete seasonal data was affected by the powders being tested at any particular time.

Table 35: Monthly means from the 1979/80 season for the 'taint' characteristic in the aroma of non-vitaminized and vitaminized whole milk powders.

	MONTH									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
Non-vitaminized	2.5	2.9	1.4	2.9	2.9	7.7	5.8	-	3.5	NS
Vitaminized	2.6	1.7	-1.7	-1.0	2.5	1.2	5.5	2.0	1.0	*

Analysis of data from the 1980/81 dairying season (shown in Appendix 15) also showed a slight seasonal effect in this attribute. The vitaminized note was not included in this category during the second season (there was a separate category for it) so that the vitaminized powders should no longer have affected this characteristic. Again, it is rather difficult to see any particular trend in the adjusted monthly means (see Table 35). When the early and late season data were analysed separately, a significant seasonal effect was found in the early season data only (see Appendix 16). The fortnightly means for these data (shown in Table 36) showed a rather erratic pattern, no clear trend being visible.

Table 36: Fortnightly means from the 1980/81 early season data for the 'taint' characteristic in the aroma of whole milk powders.

	FORTNIGHT				
	Late Aug	Early Sep	Late Sep	Early Oct	Late Oct
Taint	3.1	1.7	3.9	1.2	4.7 *

It should be remembered that this particular category was a 'catch all' one to represent odd aroma and flavour characteristics which were often inexplicable and defied clear description. Because the category was very ill-defined, the seasonal effects should be viewed with some caution.

The 'vitaminized' characteristic which had been included in the 'taint' category during the 1979/80 season, showed a significant (at the 1% level) seasonal effect in data from the 1980/81 season (see Appendix 15). The monthly means for these data (see Table 37) showed a rather erratic pattern, no clear seasonal trend being apparent. There were no significant early and late seasonal trends (see Appendix 16) and it is felt that, as in data for the 'taint' characteristic, the significant seasonal effect found in these data was influenced by the powders evaluated during any particular month.

Table 37: Monthly means from the 1980/81 season for the 'vitaminized' characteristic in the aroma of whole milk powders.

	MONTH									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
1980/81 Season	8.3	8.5	9.0	8.6	4.1	3.9	5.9	6.1	5.4	**

The seasonal effects found in these 'other' or 'additional' characteristics in the powder aroma were not as strong or as consistent as those found in the 'basic' characteristics of sweetness, butteriness and cooked/caramelised.

7. SEASONAL EFFECTS ON THE AROMA OF THE RECONSTITUTED MILKS

As in the aroma of the powders, the aroma of the reconstituted milks was divided into 'basic' characteristics of sweetness, butteriness and cooked/caramelised with 'other' lactone-like, oxidised, feedy, vitaminized, taint and age-related characteristics.

7.1 Seasonal Effects on 'Basic' Aroma Characteristics of the Reconstituted Milks

As in the powder aroma, the sweet, buttery and cooked/caramelised notes all showed highly significant seasonal effects during the 1979/80 dairying season (see Appendix 17). Monthly means for these three attributes (shown in Table 38) followed very similar patterns. Sweet, buttery and cooked/caramelised aroma characteristics rose in the second month of the season, fell in October and stabilised mid-season only to rise again sharply during April (the last month of the season).

Table 38: Monthly means from the 1979/80 and 1980/81 seasons for the sweet, buttery and cooked/caramelised notes in the aroma of the reconstituted milks.

	MONTH									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
Sweetness:										
1979/80 Season	3.2	3.7	3.4	3.8	3.9	4.1	4.0	3.6	4.4	**
1980/81 Season	4.0	4.0	4.0	4.1	4.1	4.0	4.3	4.4	4.2	**
Butteriness:										
1979/80 Season	3.0	3.4	2.7	3.1	3.1	3.2	3.0	2.9	3.5	***
1980/81 Season	3.2	3.2	3.2	3.4	3.4	3.3	3.2	3.6	3.4	***
Cooked/Caramelised:										
1979/80 Season	2.6	3.6	2.6	2.8	3.0	2.8	3.0	3.1	3.1	***
1980/81 Season	2.6	2.7	2.8	2.4	2.8	2.6	2.8	2.8	2.8	NS

When the data were split into data from non-vitaminized and vitaminized powders, the non-vitaminized powder showed significant seasonal effects in each of the three attributes (see Appendix 18). Monthly means for these non-vitaminized powders (shown in Table 39) indicated similar trends to those found in the complete seasonal data for 1979/80. In each of these three attributes, there was an increase in intensity in September and then a significant drop in intensity in October. There was then a gradual rise in each of these three attributes towards the end of the season. The sharp increase in these attributes in September corresponded with the late onset of spring in 1979. This was followed by a relatively stable mid-season period before a period of change with the onset of the autumn rains. These changes were not as marked in the non-vitaminized powders as they had been in the complete seasonal data.

Table 39: Monthly means from the 1979/80 season for the sweet, buttery and cooked/caramelised notes in the aroma of non-vitaminized and vitaminized reconstituted milks.

	MONTH									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
Sweetness:										
Non-vitaminized	3.2	3.9	3.4	3.5	4.2	4.0	4.0	-	4.3	**
Vitaminized	3.3	3.7	3.4	3.9	3.8	4.1	3.9	3.6	4.5	**
Butteriness:										
Non-vitaminized	2.7	3.5	2.5	3.0	3.3	3.2	3.0	-	3.4	***
Vitaminized	3.2	3.4	2.9	3.2	3.0	3.2	2.9	3.0	3.7	NS
Cooked/Caramelised:										
Non-Vitaminized	2.4	3.6	2.6	2.5	3.1	3.1	3.2	-	3.5	**
Vitaminized	2.7	3.8	2.5	2.8	2.8	2.4	2.8	3.1	2.9	***

Data from the vitaminized powders (see Appendix 18) showed that the seasonal effect remained significant in the sweet and cooked/caramelised aroma characteristics. The seasonal effect in these attributes for the vitaminized powders was rather unclear. As displayed in the monthly means for these powders (see Table 39), there was a sharp increase in these two notes during the second month. The means for sweetness in the aroma then indicated a gradual (but rather erratic) rise towards the end of the season. However, the means for the cooked/caramelised note indicated that the intensity of this attribute was seen to tail off towards the end of the season. Both of these attributes were significantly affected by specification. The testing of particular specification powders may well have influenced these monthly means due to confounding of the main effects. Although seasonal effects are still significant in two of these attributes, the addition of vitamins to the powders appeared to mask, at least partially, the seasonal pattern.

Analysis of data from the 1980/81 season (shown in Appendix 19) showed significant seasonal effects in both sweet and buttery aroma characteristics. The monthly means for the second season (see Table 38) indicated that seasonal changes were not as dramatic in these attributes as they had been during the first season. These three attributes were generally perceived as being less intense at the beginning of the season. There was a gradual rise in the intensity of these aroma characteristics towards the end of the season, means for March being quite significantly higher than other means. A slight drop back occurred in the final month of the season. The fact that these changes were gradual was reflected in the analyses of the early and late season data (see Appendix 20). Only in the attribute of sweetness for the late season data was there a significant change. The fortnightly means for these data (see Table 40) showed a distinct rise in sweetness during March followed by a decrease in intensity during April.

Table 40: Fortnightly means from the 1980/81 late seasonal data for the sweet note in the aroma of the reconstituted milks.

	FORTNIGHT				
	Late Feb	Early Mar	Late Mar	Early Apr	Late Apr
Sweetness	4.2	4.4	4.6	4.2	4.0 **

Over the entire season, it appeared that these attributes were generally lower in intensity during the first three months of the season than later in the season. Changes shown in the 1980/81 season data are very gradual. Specification effects were highly significant (at the 0.1% level) in all three of these attributes. The testing of certain specification powders during a particular month will have further confused the seasonal effects (due to confounding of the main effects).

7.2 Seasonal Effects on 'Other' Aroma Characteristics in the Reconstituted Milks

The '<u>oxidised</u>' note in the aroma of the reconstituted milks also showed a significant seasonal effect during the 1979/80 season (see Appendix 21). This note varied in certain powders of different specification, powders containing high levels of iron being considered to have quite strong oxidised characteristics in the aroma. This specification effect may well have influenced the seasonal effect. The variation between months was quite irregular (see Table 41) suggesting that this effect was outside the normal early and late season climatic effects which were significant in the sweet, buttery and cooked/caramelised notes of the aroma.

Table 41: Monthly means from the 1979/80 and 1980/81 seasons for the 'oxidised' note in the aroma of the reconstituted milks.

	MONTH									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
1979/80 Season	2.4	1.2	2.5	0.4	0.7	0.4	-0.7	3.3	0.6	**
1980/81 Season	5.0	5.3	5.0	4.6	6.0	4.3	6.7	5.9	6.3	NS

When the data were split into vitaminized and non-vitaminized powders, the seasonal effect became much weaker and was only significant in the vitaminized powders (see Appendix 22). The specification effect became much more significant and will undoubtedly have influenced the seasonal effect. The pattern of the monthly means (see Table 42) is again very erratic and appears to be outside the general seasonal trend of other aroma notes in the reconstituted milk.

Table 42: Monthly means from the 1979/80 season for the 'oxidised note' in the aroma of non-vitaminized and vitaminized reconstituted milks.

	MONTH									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
Non-vitaminized	2.4	0.9	2.5	0.4	0.4	0.4	0.4	-	0.2	NS
Vitaminized	2.4	1.7	2.6	0.6	0.5	0.3	-1.5	3.5	1.1	*

Analysis of data from the 1980/81 dairying season (see Appendix 23) showed that specification only had a significant effect on this attribute. The monthly means (shown in Table 41) showed no particular trend. Scores for this attribute were higher during the second season, possibly indicating better definition of this attribute. These results suggested that the seasonal effect found in the first season may well have been caused by the types of powders being tested at a particular time in the season.

The 'feedy' note in the aroma of the reconstituted milks also indicated a significant seasonal effect during the 1979/80 dairying season (see Appendix 21). Although a seasonal effect was indicated, this was probably affected by the significant factory and specification effects. The monthly means for these data (shown in Table 43) indicated that 'feedy' notes were stronger at the beginning and end of the season, when pasture growth is greatest.

Table 43: Monthly means from the 1979/80 and 1980/81 seasons for the 'feedy' note in the aroma of the reconstituted milks.

	MONTH									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
1979/80 Season	7.3	10.2	4.7	5.0	2.9	2.8	7.4	9.4	5.1	**
1980/81 Season	9.0	9.0	9.0	9.9	6.1	7.3	7.2	10.4	11.6	NS

When the data were split into data from vitaminized and non-vitaminized powders, the seasonal effect disappeared entirely (see Appendix 22). This suggested that the seasonal effect found in the complete data was, in part, influenced by the testing of certain specification powders during a particular month.

Data from the 1980/81 dairying season (see Appendix 23) showed no significant seasonal effect for this characteristic of the aroma. The adjusted monthly means for these data (see Table 43) again suggested that 'feedy' notes were stronger during the early and late season periods. This 'feedy' note was often confused with a distinctive note in certain vitaminized powders and more study is required to determine whether there is a true seasonal effect in this characteristic.

A weak seasonal effect was indicated in the 'lactone-like' note during the 1980/81 season (see Appendix 23). This seasonal effect had not been present in data from the 1979/80 season (see Appendix 21). The monthly means for this attribute (see Table 44) showed a rather erratic pattern and there were no significant early or late season effects (see Appendix 24). This 'lactone-like' characteristic was associated with certain vitaminized powders and there were strong specification effects in data from both seasons. This weak seasonal effect will have been influenced by the testing of certain vitaminized powders during a particular month.

Table 44: Monthly means from the 1979/80 and 1980/81 seasons for the 'lactone-like' note in the aroma of the reconstituted milks.

	MONTH									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
1979/80 Season	4.9	4.5	2.7	6.9	6.0	5.7	5.6	4.4	8.6	NS
1980/81 Season	7.0	6.6	6.9	6.3	8.9	3.5	4.5	4.6	5.6	*

8. SEASONAL EFFECTS ON THE FLAVOUR OF THE RECONSTITUTED MILKS

As in the aroma of both powders and reconstituted milks, the flavour of the reconstituted milks was divided into 'basic' characteristics of sweetness, creaminess and cooked/caramelised with 'other' lactone-like, oxidised, feedy, vitaminized, taint and age-related characteristics.

8.1 Seasonal Effects on the 'Basic' Characteristics in the Flavour of the Reconstituted Milks

The sweet, creamy and cooked/caramelised flavours in the reconstituted milks showed significant seasonal effects during the 1979/80 season (see Appendix 25). The monthly means for these three attributes (see Table 45) showed similar patterns for all three attributes. The sweet, creamy and cooked/caramelised notes rose in the second month of the season only to fall in the third month and to stabilise mid-season. There was a sharp rise again during the final month of the season. These trends were very similar to those found in the aroma and seemed to follow climatic changes in the season.

Table 45: Monthly means from the 1979/80 and 1980/81 seasons for the sweet, creamy and cooked/caramelised notes in the flavour of the reconstituted milks.

	MONTH									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
Sweetness:										
1979/80 Season	3.7	4.0	3.9	3.9	4.4	4.4	4.6	4.1	4.7	**
1980/81 Season	4.5	4.4	4.3	4.5	4.4	4.6	4.7	5.0	4.7	***
Creaminess:										
1979/80 Season	3.2	3.6	3.3	3.6	3.8	4.0	4.0	3.6	4.3	***
1980/81 Season	3.3	3.5	3.5	3.9	4.0	4.0	4.2	4.2	4.1	***
Cooked/Caramelised:										
1979/80 Season	2.6	3.7	2.5	3.0	3.1	2.9	3.3	2.7	3.3	***
1980/81 Season	2.8	2.7	2.8	2.6	2.6	2.6	2.8	2.7	2.8	NS

Data for these three flavour attributes were split into data from non-vitaminized and vitaminized powders. Analyses of these data showed (see Appendix 26) that seasonal effects remained significant in all but the sweetness of the non-vitaminized powders. The monthly means for these attributes in the two groups of powders showed (see Table 46) rather similar patterns to the means for the complete seasonal data. In the non-vitaminized powder, there was a sharp rise in intensity during September for all three attributes. The sweet flavour then showed a rather erratic pattern to the end of the season, tending to rise towards the end of the season. Creaminess and cooked/caramelised flavours dropped back in the third month, creaminess then tended to rise towards the end of the season. The cooked/caramelised flavour note also increased in intensity towards the end of the season, dropping back during the final month. The vitaminized powders showed a sharp rise in flavour intensity during September then a relatively stable mid-season period followed by a sharp rise in the final month.

Table 46: Monthly means from the 1979/80 season for the sweet, creamy and cooked/caramelised notes in the flavour of non-vitaminized and vitaminized reconstituted milks.

	MONTH									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
Sweetness:										
Non-vitaminized	3.9	4.3	4.2	4.2	4.8	4.7	4.9	-	4.8	NS
Vitaminized	3.6	3.9	3.8	3.8	4.1	4.2	4.5	3.9	4.7	*
Creaminess:										
Non-vitaminized	3.4	3.6	3.4	3.7	4.5	3.9	4.1	-	4.2	**
Vitaminized	2.9	3.5	3.1	3.5	3.4	3.9	3.7	3.4	4.2	**
Cooked/Caramelised:										
Non-vitaminized	3.3	4.2	2.9	3.2	3.7	3.0	3.6	-	3.5	***
Vitaminized	2.5	3.7	2.5	3.1	3.0	3.0	3.3	2.8	3.5	***

Data from the 1980/81 season showed (see Appendix 27) that there was a highly significant seasonal effect in both sweetness and creaminess.

The monthly means (shown in Table 45) for these three attributes indicated that, as in the attributes of the aroma, seasonal trends during this season were much less marked than in the 1979/80 season. In general, the intensity of these attributes during the first three months was lower than during the rest of the season, there being a gradual rise in intensity towards the end of the season.

The gradual seasonal changes seen in the complete seasonal data from the 1980/81 season were reflected in the analysis of the early and late season data (see Appendix 28). These showed significant seasonal effects in the late season data for the sweet note only. The fortnightly means for these data (shown in Table 47) indicated that there was a distinct rise in sweetness during March which dropped away again in April.

Table 47: Fortnightly means from the 1980/81 late season data for the sweet note in the flavour of the reconstituted milks.

	FORTNIGHT				
	Late Feb	Early Mar	Late Mar	Early Apr	Late Apr
Sweetness	4.6	5.1	5.0	4.6	4.7 **

8.2 Seasonal Effects on 'Other' Characteristics in the Flavour of the Reconstituted Milks

One attribute in which a seasonal effect had been expected was in the 'feedy' note in the flavour of reconstituted milk powders. It has long been thought that products processed very early in the season will tend to have 'feedy' characteristics not present later in the dairy season. It had been hoped that whole milk powders would show this effect. However, analysis of the data from the 1979/80 season for this particular flavour note showed only factory and specification effects. During the first season there was some confusion over this note, it being associated with certain specification powder containing added vitamins and minerals. The monthly means for this attribute (see Table 48) show a very erratic pattern, the types of powders evaluated at a particular time influencing these means.

Table 48: Monthly means from the 1979/80 and 1980/81 season for the 'feedy' note in the flavour of the reconstituted milks

	MONTH								
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1979/80 Season	2.6	2.2	2.0	3.4	2.6	2.0	2.1	2.3	2.0 NS
1980/81 Season	5.2	2.9	3.3	2.3	1.6	1.9	1.4	3.5	3.3 **

Before the 1980/81 season began, this characteristic was re-defined by the panel and notes associated with vitaminized powders put into a separate category. Thus, it was hoped that much of the confusion over this particular attribute would be removed. Analysis of the data from the 1980/81 season showed that there was in fact a significant (at the 1% level) seasonal effect in this attribute (see Appendix 31). The adjusted monthly means (see Table 48) showed that powders processed in August were significantly more 'feedy' in flavour than any other time in the season. Detailed analysis of the early season data (see Appendix 32) showed that there were still significant factory, specification and seasonal effects. The fortnightly means (see Table 49) indicated that the powders processed in late August were considered to have a strong 'feedy' note which dropped away in September and early October. This 'feedy' note inexplicably rose again in late October. This effect will have been influenced by the factory and specification effects (due to confounding of the main effects).

Table 49: Fortnightly means from the 1980/81 early season data for the 'feedy' note in the flavour of the reconstituted milks.

	FORTNIGHT				
	Late Aug	Early Sep	Late Sep	Early Oct	Late Oct
Feedy	5.7	3.7	2.9	3.0	6.0 *

Generally, the data suggested that whole milk powders processed at the very beginning of the season were more 'feedy' than at any other time during the season. There was some confusion in that certain powders containing high levels of vitamins and minerals were 'feedy' also. Should powders processed during this very early period be objectionable to the consumer, the production of certain vitaminized specification powders at this time would effectively mask any 'feedy' notes due to seasonal effects.

Season also had a significant effect on the 'taint' flavour characteristic during the 1979/80 season (see Appendix 29). The adjusted monthly means (see Table 50) showed a rather erratic pattern, increasing mid-season and again late season. When data from the 1979/80 season were split into data from non-vitaminized and vitaminized powders, it was found that this seasonal effect was common to both groups of powders (see Appendix 30). This 'taint' characteristic showed no seasonal effect during the 1980/81 season (see Appendix 31) although there were significant factory and specification effects in these data.

Table 50: Monthly means from the 1979/80 and 1980/81 seasons for the 'taint', 'vitaminized', 'oxidised' and 'age-related' flavours in the reconstituted milks.

	MONTH									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
Taint:										
1979/80 Season	2.3	0.4	1.2	3.9	4.1	2.3	4.8	7.8	6.2	**
1980/81 Season	0.8	2.9	2.3	3.9	1.8	2.1	3.1	2.9	2.3	NS
Vitaminized:										
1980/81 Season	21.3	21.1	21.5	21.7	15.8	17.3	15.7	17.3	16.1	**
Oxidised:										
1979/80 Season	4.5	3.2	4.0	4.0	2.6	4.7	2.6	9.8	3.1	NS
1980/81 Season	5.0	7.0	8.7	10.8	8.4	5.9	9.8	10.7	10.8	***
Age-related:										
1979/80 Season	1.0	0.8	0.3	0.7	0.5	2.1	0.3	-0.5	2.9	NS
1980/81 Season	0.6	0.6	0.2	1.4	0.7	-0.5	1.6	1.4	0.7	*

Certain distinctive flavour characteristics associated with vitaminized powders were placed in the 'taint' category during the 1979/80 season. During the 1980/81 season these characteristics were put into a separate category and this 'vitaminized' flavour showed a significant seasonal effect (see Appendix 31). The adjusted monthly means for this attribute showed a rather erratic pattern (see Table 50). Similarly, the 'oxidised' and 'age-related' flavours showed significant seasonal effects during the 1980/81 season (see Appendix 31) but the monthly means showed no clear seasonal patterns (see Table 50). Analysis of the early and late season data from the 1980/81 season showed that some of these seasonal effects remained significant (see Appendix 32) but the means indicated no clear seasonal trends (see Table 51).

Table 51: Fortnightly means from 1980/81 early and late season data for the 'oxidised', 'vitaminized' and 'age-related' flavours in the reconstituted milks.

	FORTNIGHT					
Early Season Data:						
	Late Aug	Early Sep	Late Sep	Early Oct	Late Oct	
Oxidised	4.8	5.5	8.2	9.1	12.1	*
Vitaminized	20.3	19.2	22.9	21.8	20.6	NS
Age-related	0.7	0.9	0.4	0.3	0.3	NS
Late Season Data:						
	Late Feb	Early Mar	Late Mar	Early Apr	Late Apr	
Oxidised	10.1	10.6	13.3	15.3	10.8	*
Vitaminized	15.2	21.1	17.4	14.7	17.7	*
Age-related	2.4	1.5	1.8	1.9	0.8	NS

The 'taint', 'vitaminized', 'oxidised', and 'age-related' flavours were all associated with certain specification powders. Data from each of these flavour attributes indicated strong specification effects and the seasonal effects will undoubtedly have been influenced by the types of powders tested at any particular time. It becomes questionable as to how much importance should be attached to the seasonal effects in these attributes. In addition, the 'taint' characteristic was a 'catch-all' category for ill-defined flavours, which casts further doubt upon the importance of this seasonal effect. None of the seasonal effects shown in the 'other' flavour characteristics were as consistently strong as those found in the sweet, creamy and cooked/caramelised flavours which made up the 'basic' profile of the reconstituted milks.

9. DISCUSSION AND CONCLUSIONS

McDowell and Creamer (1970) have shown that because New Zealand depends on a seasonal pasture as feed for its dairy cattle, marked changes occur in dairy products processed at different times during the dairy season. This has been shown to be particularly true of dairy products processed during the early spring 'flush' and in the late autumnal period.

Seasonal changes were found to affect certain physical properties of the powders, such as the colour. Previous studies of New Zealand dairy products had shown that the colour of the milkfat, due to its β-carotene content, drops sharply at the beginning of the season from a very high level to stabilise during the middle of the season, only to rise again at the end of the season (McDowell 1956). Sensory data from the 1979/80 dairying season showed that this change in colour was perceptible in whole milk powders. Powders produced at the very beginning and very end of the season were significantly brighter in colour than powders processed mid-season. The perceived viscosity and astringency of the reconstituted milks were also strongly affected by seasonal changes. The greatest changes in these two properties occurred late in the season, both viscosity and astringency increasing late in the season. During the late seasonal period a number of changes in both composition and functional properties of the milk occur. In particular, there are changes in the protein:lactose ratios and it is thought that such changes may be associated with these changes in the perceived viscosity and astringency of the reconstituted milks.

The sensory data for attributes in the aroma and flavour of the whole milk powders, indicated that season had a highly significant effect on the 'basic' notes in the aroma and flavour of whole milk powders. These sweet, buttery and cooked/caramelised notes had been defined by the panel as making up the 'basic' or 'normal' profile of whole milk powders. The adjusted monthly means for these attributes showed clear seasonal patterns in these sensory attributes. These seasonal patterns were not exactly the same for the two dairying seasons but appeared to reflect climatic changes occurring during these seasons.

The spring of 1979 was very dry and the onset of the spring 'flush' was late. This was reflected in marked changes in the sweet, buttery and cooked/caramelised notes in the aroma and flavour during September 1979 corresponding to the spring 'flush'. Sensory attributes then indicated a relatively stable mid-season period before a sharp increase in aroma and flavour notes during April (the last month of the season). The onset of autumn was quite sudden in the 1979/80 dairying season and this was reflected in abrupt changes in the sensory properties. Changes in both composition and functional properties of milk occur during this period but the effect of these late season changes on the sensory properties of whole milk powders had not previously been recorded.

Because data from these critical early and late season periods had been very sparse in the 1979/80 season, as many samples as possible were tested from these two periods in the 1980/81 dairying season. Analysis of data from the 1980/81 season again showed significant seasonal effects in the 'basic' aroma and flavour characteristics. In general, the trends in the second season were much less marked than those found in the 1979/80 season. This seemed to be a reflection of differences in the climatic pattern of the 1980/81 season. The spring of 1980 was very wet and the spring 'flush' was very early. The earliest powders processed in the 1980/81 season were processed some two weeks later than in the previous season. This lag time, together with differences in the onset of the spring 'flush', meant that very early seasonal effects were not well 'caught' in data from the 1980/81 season. Generally, the aroma and flavour notes were low in intensity during the first three months of the 1980/81 season and then rose gradually towards the end of the season. The late seasonal period showed very gradual changes rather than the abrupt changes shown in the 1979/80 season. This was thought to be a reflection of an unusually wet late summer and autumnal period ensuring even pasture growth. The fact that these changes were gradual meant that detailed study of the early and late season periods did not make the form of these changes much clearer.

It had been thought that changes in the pasture might be reflected in changes in the flavour of the whole milk powders. Kinsella (1969) has pointed out that the lipid components of milk (which change as the pasture matures) are undoubtedly the most important source of flavour in dairy products. Milkfat, because of its complex composition, can generate a multitude of flavour compounds, some of which are desirable, some undesirable. Many of these compounds are produced by oxidative processes. Not all such compounds produce objectionable flavours. For example, the compound cis-4-heptenal, which arises from the oxidation of linoleic acid, imparts a 'creamy' flavour to milkfat.

Aldehydes, such as cis-4-heptenal, are the result of breakdown of the unsaturated fats in the milk. It has been found that measurement of the total aldehyde content of milkfat gives some indication of the intensity of this 'creamy' flavour. Keen (1981, personal communication) has shown that the total aldehyde content of milkfat increases from a low level at the beginning of the season, stabilising mid-season and decreasing again during the late summer and early autumn. It is interesting to note that the 'creamy' flavour in the reconstituted milk powders appeared to follow this seasonal pattern. There was a gradual increase in the intensity of this flavour in the early part of the season before a stable period of approximately three months was reached. Creaminess then increased again (somewhat inexplicably) at the very end of the season. However, in the 1980/81 seasonal data creaminess tailed away at the end of the season (following the seasonal pattern for total aldehyde content).

Seasonal effects shown in data for the 'other' aroma and flavour attributes in whole milk powders were not as marked or as consistent as those found in the 'basic' aroma and flavour notes. The adjusted monthly means showed no particular pattern and changes between months appeared to be rather erratic. It was felt that these were influenced by the specification powders tested in a particular month (due to confounding of the main effects). One exception to this general trend was the feedy note in the flavour of the reconstituted milks. During the 1979/80 season this attribute showed no seasonal effect, merely a specification effect. However, in the 1980/81 season when this attribute had been re-defined there was a significant seasonal effect (as had been expected). In this attribute, the seasonal effect became apparent once the panel had re-defined their terms.

Data from the 1980/81 season, when these terms were better defined, suggested that many of the 'other' or 'additional' attributes were strongly affected by the addition of vitamins rather than by seasonal effects. It is felt that the seasonal effects on these particular attributes are extremely doubtful, except perhaps for a slightly early season effect on the feedy note in the flavour of reconstituted milks.

To summarise; the data collected during two dairying seasons clearly showed that season had a significant effect on a number of sensory properties in whole milk powders. These seasonal effects were highly significant in the colour of the powders and textural attributes of the reconstituted milks. In the aroma and flavour of the whole milk powders, the 'basic' aroma and flavour notes of sweetness, butteriness and cooked/caramelised were most affected by season. These three attributes followed similar patterns throughout the season. Thus, the attributes which make up the 'basic' profile of this product were all affected by season. The 'additional' aroma and flavour attributes, while showing slight seasonal effects, were more significantly affected by processing changes, such as the addition of vitamins.

CHAPTER VIII

EFFECT OF CERTAIN PROCESSING VARIABLES ON SENSORY PROPERTIES OF WHOLE MILK POWDERS

1. INTRODUCTION

When the present study was set up, it was expected that seasonal effects would cause major changes in whole milk powders but that some slight differences might be caused by different factory regimes and equipment. The treatment of the milk from when it was first received at the factory until it was converted into whole milk powder, differed in individual factories. Among the five participating factories, there were several different types of spray driers and the layout of the drying operation differed. This meant that there were differences between factories in the evaporation, drying, agglomeration and lecithination of powders.

During the 1979/80 dairying season, it became increasingly clear that different specification milk powders had characteristic sensory properties. Differences were not limited to physical properties, such as colour and particle size. In addition, there were differences in both the aroma and flavour of the whole milk powders. These differences in the aroma and flavour of powders and reconstituted milks were quite unexpected, as they had not previously been documented. The data from the 1979/80 dairying season showed clearly that powder specifications containing vitamins and iron had different sensory characteristics. Characterization of these powders containing vitamin preparations was continued during the 1980/81 dairying season as part of the continuing evaluation of commercial whole milk powders.

Before the 1980/81 season began, the 'other' or 'additional' categories, so important in the characterization of these powders, were re-defined in greater detail. These additional categories were divided into: 'lactone-like', 'oxidised', 'feedy', 'taint', 'age-related' and a new category called 'vitaminized'. A commercial powder specification containing a preparation of Vitamins A, B_1, C and D was defined as having a typical 'vitaminized' aroma and flavour.

2. METHODS

2.1 Sampling Methods

The study of the processing effects on commercial whole milk powders was carried out on the same powders used to study the effect of seasonal changes. The samples were those taken for the seasonal work (as described in Methods 2.2).

The five participating factories produced milk powders of three major types: non-agglomerated, agglomerated and agglomerated/lecithinated (referred to in the subsequent text as 'instantized'). These three major powder types could be further divided into those milk powders which were vitamin fortified and those which were not (see Table 52). No factory made all these six groups of powders. Twenty three powder specifications were tested during the 1979/80 and 1980/81 dairying seasons. These specifications included powders fortified with vitamins and iron, as shown in Table 53. The attributes of these individual powder specifications are discussed using the specification numbers in this table.

Table 52: Major whole milk powder types processed by participating factories during the 1979/80 and 1980/81 dairying season.

	Non-Agglomerated		Agglomerated		Agglomerated/ Lecithinated	
Factory	No Vitamins	+ Vitamins	No Vitamins	+ Vitamins	No Vitamins	+ Vitamins
1	X	X		X		X
2	X	X				X
3	X	X				
4	X	X		X	X	X
5	X	X	X	X		X

2.2 Methods of Statistical Analysis

The statistical analysis of the seasonal data (described in the previous chapter) also showed the significance of processing effects. This meant that all significant factory and specification effects could be influenced by seasonal effects. For example, a specification effect could be influenced by the seasonal period in which that particular powder was processed.

In addition, there were several factors bound up in any of the factory effects. The participating factories are situated in three distinct climatic regions. It is possible that climatic factors may influence this effect, powders produced in a certain region being significantly different throughout the season. Herd effects may also influence the factory effects. Keen and Udy (1980) have shown significant breed differences between milk from Jersey and Friesian cows, the two major breeds found in New Zealand dairy herds. The predominant breed varies from region to region and such breeds differences will also influence the factory

Table 53 : Whole milk powders tested during the 1979/80 and 1980/81 seasons indicating fat content and powders which are fortified with vitamins and iron.

	Fat	Vitamins				
Specification	Content	A	B_1	C	D	IRON
Non-agglomerated powders:						
1	26%					
2	26%					
3	26%					
4	26%					
5	28%					
6	26%	X			X	
7	26%	X			X	
8	26%	X	X	X	X	X
9	26%	X			X	
10	28%					
11	28%					
Agglomerated powders:						
12	28%	X			X	
13	27%	X			X	
14	26%					
Agglomerated/lecithinated powders:						
15	28%	X			X	
16	28%	X	X	X	X	
17	27%	X			X	
18	28%	X			X	
19	28%	X			X	
20	28%					
21	26%	X			X	
22	28%	X			X	
23	26%	X	X	X	X	X

effect. In addition, equipment differs among factories and this may also influence the factory effect. It must also be remembered that, depending on the characteristics of individual powders, factory effects may be the results of certain specification powders being processed at one factory only (due to confounding of the main effects).

The interpretation of these significant specification and factory effects was therefore approached with some caution, with careful study of other factors significantly affecting the same attributes.

3. EFFECT OF CERTAIN PROCESSING VARIABLES ON THE PHYSICAL PROPERTIES OF WHOLE MILK POWDERS

Certain processing variables were found to have a significant effect on the physical properties of the powders but not on physical properties of the reconstituted milks, such as viscosity and astringency.

3.1 Colour

Data from the 1979/80 season for colour in whole milk powders (see Appendix 3) showed that powders from different factories differed in colour. Powders from Factory No. 3 were significantly paler in colour than powders from other factories. Factory No. 3 made no agglomerated powders which were generally higher in colour (due to the larger particle size) than non-agglomerated powders. Powders from Factory No. 4 had a higher overall score than any other factory. Agglomerated powders from this particular factory had a larger mean particle size than those from other factories. Powders with a larger particle size were brighter in colour. Because of the larger particle size in all powders from Factory No. 4, these powders were brighter in colour than powders from other factories. Factory No. 4 has a drier which is unique in New Zealand. Whether the greater degree of agglomeration which this factory was able to achieve was a direct result of the drier type or some other unique factor in their processing regime was unclear.

There was also a significant specification effect in the colour of whole milk powders (see Appendix 3). The means indicated that differences in colour were associated with the particle size. Powders with a larger particle size were more yellow or brighter in colour than those with a small particle size. The agglomerated powders and those which were partially agglomerated were similar in colour and more yellow than non-agglomerated powders. There were some slight discrepancies in this general trend. These were caused by confounding of the main effects. If an agglomerated powder was processed only late in the season, when colour was paler than in the early season period, the overall mean for such a powder was lower than for powders processed throughout the season. Thus, highly significant seasonal changes in colour influenced certain specification effects.

3.2 Free-flowing Properties

Powders from different factories showed different free-flowing properties during the 1979/80 season (see Appendix 4). Factory No. 3 produced powders which were significantly less free-flowing than other powders. As discussed previously, this factory made only non-agglomerated powders. Powders from Factory No. 4 were significantly more free-flowing than other powders. Powders from this factory had a higher mean particle size than other powders. Since particle size was found to influence the perception of free-flowing properties, this will have influenced the factory effect.

Powder specification had a significant effect on the free-flowing properties in whole milk powders (see Appendix 4). The means showed that these differences were associated with the physical structure of the powder. Powders with a larger particle size were more free-flowing than those with a small particle size. However, in this attribute there were also differences between agglomerated and instantized powders, both of which had a large particle size. The agglomerated powders were considered to be the most free-flowing of all powders tested. The instantized powders were considered less free-flowing, 'stickier' than these powders. The addition of 0.2% lecithin to these 'instantized' powders caused a perceptible change in their free-flowing properties. The non-agglomerated powders were considered to be the least free-flowing of the three powder types.

3.3 Particle Size

Specification had the only significant effect on the particle size of whole milk powders (see Appendix 4). This specification effect was due to the physical structure of the powder. Agglomerated powder had a significantly larger particle size than non-agglomerated powders. Partially agglomerated powders were similar in particle size to the agglomerated powders.

4. EFFECT OF CERTAIN PROCESSING VARIABLES ON THE AROMA AND FLAVOUR OF WHOLE MILK POWDERS

Certain processing variables had a significant effect on the sweet, buttery and cooked/caramelised notes which made up the 'basic' profile of whole milk powders. The relationship between processing variables, such as the addition of iron, and these attributes was often an inverse one. These three notes tended to be less intense when 'other' intense notes were present. No longer did these 'basic' aroma and flavour attributes characterize the changes taking place as they had in the seasonal effects. Instead, the 'other' sensory attributes were vital in describing the effects which vitamin and iron addition had on the sensory properties of whole milk powders.

4.1 Aroma of Powder

Data from the 1979/80 and 1980/81 seasons showed significant factory and specification effects in sweet and buttery notes of the powder aroma. However, data from these two seasons indicated that neither factory nor specification had a significant effect on the cooked/caramelised note in the powder aroma.

Analysis of the data from the 1979/80 season for the sweet note in the powder aroma (see Appendix 9) showed significant factory (at the 5% level) and specification (at the 1% level) effects. There was some variation in the sweetness of powders among factories. Powders produced by Factory No. 5 were significantly sweeter than powders from other factories. Individual processing regimes within the factories, particularly in the preheat treatment of the milk, may have affected this result.

There was also a significant specification effect (see Appendix 9), different specification powders varying in sweetness. Specification No. 9 was significantly sweeter and Specification No. 13 significantly less sweet than other powders. Both powders contained additional Vitamin A and D, as do several other powder specifications. Specification No. 9 contains only a low level of Vitamins A and D. At this low level of addition, the sweetness of the aroma was apparently enhanced. Specification No. 13, however, contains a very high level of Vitamin A and D. This high level of addition decreased the sweetness of the powders.

Significant factory and specification effects on the sweet note in the powder aroma were also found during the 1980/81 season (see Appendix 11). Powders produced by Factories No. 2 and No. 5 were slightly less sweet than those from other factories during the 1979/80 season. The fluctuation in this factory effect from season to season, suggests that it was influenced by the particular specification powders processed in a factory (due to confounding of the main effects). Data from the 1980/81 season (see Appendix 11) showed a slight specification effect also, specification No. 23 being slightly less sweet than other powders. This powder contained a high level of vitamins and iron. The effect of these additions was to mask the more 'basic' note of the milk powder profile.

The buttery note in the powder aroma showed a highly significant (at the 0.1% level) specification effect during the 1979/80 season (see Appendix 9). Powder specification No. 23 was significantly less buttery than other powders. Powder specification No. 9, which contained only a very low level of Vitamins A and D, was significantly more buttery than other powders. This low level of vitamin addition again enhanced this aroma characteristic. Analysis of data from the 1980/81 season showed a significant (at the 0.1% level) factory effect but no specification effect (shown in Appendix 11). The aroma of powders from Factory No. 2 was less buttery during the 1980/81 season. These effects will have been influenced by the specification powders processed by this particular factory, due to confounding of the main effects. However, it is also possible that some factor in this factory's processing regime affected this particular attribute.

The 'taint' characteristic in the powder aroma showed highly significant (at the 0.1% level) effects only in data from the 1980/81 season, when terms had been more clearly defined (see Appendix 15). Powder specification No. 15 was considered to be markedly more 'tainted' than other powders. Powder specification Nos. 17 and 21 were slightly more 'tainted' than other powders. All three powders contained Vitamins A and D, as do several other powder specifications. None of these specifications were processed by more than one factory and it was not possible to separate specification and possible factory effects.

The 'age-related' note in the aroma of whole milk powders showed a significant specification (at the 5% level) effect during the 1979/80 season (see Appendix 13). The adjusted means showed that the aroma of specification Nos. 15 and 23 was significantly more 'stale' and 'old' than that of other powders. Analysis of data from the 1980/81 season for the same characteristic (see Appendix 15) also showed a significant (at the 1% level) specification effect. The adjusted means for the different powders showed that specification Nos. 15, 17, 21 and 23 had a more 'stale' aroma than other powders. Specification Nos. 15, 17 and 21 had a more 'tainted' aroma than other powders. Certain of the vitaminized powders had an aroma which was variously described as 'stale', 'old' and 'tobacco'. These powders clearly had an aroma which differed from other powders but the panel had some difficulty in defining it clearly. These particular specifications were all instantized powders.

4.2 Aroma of the Reconstituted Milk

Specification had a significant (at the 0.1% level) effect on the sweet note in the aroma of the reconstituted milks during the 1979/80 season (see Appendix 17). The aroma of specification No. 8 was significantly less sweet than that of other reconstituted milks. This particular specification contained a high level of both vitamins and iron. The only other specification which was similar to this powder (specification No. 23) was also scored lower than the overall mean for the powders. The analysis of data from the 1980/81 season (see Appendix 19) for the sweet note in the aroma of the milk showed that in these data, specification No. 23 was very much less sweet than other reconstituted milks. In addition, specification No. 16 (which had been defined by the panel as being the typical 'vitaminized' powder) was considered significantly sweeter than other reconstituted milks.

Data from the 1979/80 season for the buttery note in the aroma of the reconstituted milks showed (see Appendix 17) no significant factory or specification effects. Analysis of data from the 1980/81 season (see Appendix 19) showed a significant (at the 0.1% level) specification effect only. Powder specification No. 23 was significantly less buttery than other powders.

Powder specification had a significant effect on the cooked/caramelised aroma of the reconstituted milks during both the 1979/80 season (see Appendix 17) and the 1980/81 season (see Appendix 19). The specification means for both seasons indicated that specification No. 16 was significantly more cooked/caramelised than other powders, specification No. 23 significantly less cooked/caramelised than other powders. These powders showed significantly different characteristics in data from both seasons. This suggested that there was an enhancing of these 'basic' notes in powders fortified with certain vitamin preparations, such as specification No. 16. However, in other specifications containing additional vitamins and iron, such as specification No. 23, these notes were hidden.

Changes in the cooked/caramelised note might be expected to arise from differences in processing conditions, particularly the heat treatment. No such processing effects were obvious in these data. Specification No. 16 was processed by three of the participating factories and had similar aroma and flavour attributes wherever it was processed. This powder had only a medium preheat treatment, the more intense cooked/caramelised note was not the result of high heat treatment. Specification No. 23 was processed by only one factory. However, this specification powder has a standard preheat treatment and there is no reason to believe that the preheat treatment significantly affected the intensity of the cooked/caramelised note in this powder.

Data from the 1979/70 season for the 'lactone-like' aroma in the reconstituted milks, indicated highly significant (at the 0.1% level) specification effects (see Appendix 21). Adjusted means for this attribute showed that specification Nos. 6, 13, 19 and 22 were more 'lactone-like' than other reconstituted milks. All these whole milk powders contained

Vitamins A and D. Some of the powders containing these vitamin preparations had a sweet 'lactone-like' note in the aroma and flavour. Analysis of data from the 1980/81 season (shown in Appendix 23) also showed a significant specification effect in this attribute. The adjusted means from these data showed that specification No. 22 only was more 'lactone-like' than other reconstituted milks.

During the 1979/80 season, these attributes of aroma and flavour were not well defined. There was no separate category to describe the aroma and flavour of vitaminized milk powders. Because of this, these powders tended to be described in terms of attributes such as 'lactone-like'. The aroma of specification No. 22 was considered to be distinctly more 'lactone-like' during both the 1979/80 and 1980/81 dairying seasons. This specification is an instantized powder containing Vitamins A and D, at a similar level to other powder specifications. This powder was processed by one factory only, so it is not possible to distinguish between the effects of vitamin addition and those of processing conditions (such as the manner of vitamin addition). This powder does have some unique physical properties. It is possible that in changing its physical properties slightly, there has been some alteration in the aroma characteristics.

The '<u>oxidised</u>' aroma in the reconstituted milks showed a significant specification effect during the 1979/80 season (see Appendix 21). The adjusted means showed that powder specification Nos. 8 and 9 had a more 'oxidised' aroma than other reconstituted milks. Specification No. 8 contains added iron which has been associated with an oxidised note in whole milk powders, even a short time after processing. However, specification No. 9 does not contain added iron. This specification was tested only twice during the 1979/80 season and more data would be required before it could be established that the aroma of this specification had a characteristic 'oxidised' note.

Before the 1980/81 dairying season began, the panel re-defined these attributes. Data from this season reflects this (see Appendix 23). The data again showed a significant specification effect, the adjusted means indicating that specification No.8 was significantly more 'oxidised' than other powders. However in these data, specification No. 23 was significantly more 'oxidised' than all other powders including specification No.8. Both specification Nos. 8 and 23 contain iron. Specification No. 8 was a non-agglomerated powder, specification No. 23 an instantized powder. Addition of iron to an instantized powder clearly had a much greater effect than the same addition to a non-agglomerated powder. Specification No. 9 was not significantly different from other powders during the 1980/81 season. This suggests that the results from the 1979/80 season were perhaps not characteristic of the powder and could have resulted from atypical samples.

Both factory and specification had a significant influence on the 'feedy' aroma of reconstituted milks in data from the 1979/80 season (see Appendix 21). Powders processed by factory No. 5 were significantly 'feedier' than other powders. This factory effect will have been influenced by the particular specifications processed during the season. Adjusted means for the different powder specification showed that the aroma of specification Nos. 7, 9 and 23 was 'feedier' than that of other reconstituted milks. On the other hand, specification Nos. 13 and 17 were significantly less 'feedy' than other reconstituted milks. The 'feedy' note in the aroma and flavour of whole milk powder was expected to result from certain cattle feeding regimes, particularly in the very early seasonal period when cattle are still receiving feed supplements to available pasture. However, there was some confusion amongst the panelists during the first season and this 'feedy' note was also associated with certain of the vitaminized whole milk powders. In the 1980/81 season, when attributes associated with 'vitaminized' powders were better defined, this specification effect was no longer significant.

During the 1979/80 season the 'taint' aroma in the reconstituted milks showed only a significant (at the 1% level) specification effect (see Appendix 21). Adjusted means showed that the aroma of specification No. 16 was significantly more 'tainted' than that of any other reconstituted milks. During the 1979/80 season it was found that vitamin fortified powders had a distinctive aroma and flavour. These distinctive notes were included in the 'taint' category. Before the 1980/81 season began, a separate category for a 'vitaminized' note was created. Specification No. 16 (which had such distinctive attributes) was used as the typical 'vitaminized' powder. Data from the 1980/81 season for the same 'taint' characteristic again showed a significant specification effect (shown in Appendix 23). However, from the adjusted means it was clear that during the 1980/81 season the category was being used by the panel for different aroma notes. The aroma of powder specification Nos. 8 and 23 was significantly more 'tainted' than other specification powders. These two specifications contained vitamins and iron and had displayed rather complex aroma attributes. Both powders had a distinctive 'oxidised' aroma but there were other notes present which the panel had more difficulty in defining.

Data for the 'vitaminized' aroma in the reconstituted milks showed only a highly significant (at the 0.1% level) specification effect (see Appendix 23). The adjusted means showed that specification Nos. 6, 8, 16 and 23 had a stronger 'vitaminized' aroma than other reconstituted milks. Specification Nos. 8 and 23 had already proved markedly different from other powders. These two specifications contained Vitamins A, B_1, C and D and added iron. Specification No. 16 contained the same vitamin mix and had been used as the standard 'vitaminized' powder. The three powders which contained this same vitamin mix were more 'vitaminized', even than other vitaminized powders. Specification No. 6 contains Vitamins A and D only, as do several other powder specifications. However, of all the powder specifications tested, specification No. 6 contains the highest level of these two vitamins. This high level of vitamin addition resulted in a stronger 'vitaminized' aroma in the reconstituted milks.

Powder specification had a significant effect on the '<u>age-related</u>' aroma in the reconstituted milks during both the 1979/80 and 1980/81 seasons (shown in Appendices 21 and 23). Both sets of adjusted means for the different specifications showed that the aroma of specification No. 23 was significantly more 'stale' than that of other reconstituted milks. Specification No. 23 was the only instantized powder which contained both vitamins and iron. It appeared that these additions in an instantized powder produced a characteristic 'stale' note present only a few days after processing. It is possible that this 'stale' note is the result of changes in the powder which cause a 'cardboard' note in this specification powder.

4.3 Flavour of the Reconstituted Milk

Both factory and specification had a significant effect on the <u>sweet</u> flavour in reconstituted milks during the 1979/80 season (see Appendix 25). The adjusted means indicated that powders from Factory No. 5 were significantly sweeter than those from other factories. Powder specification also had a significant effect on the sweetness of reconstituted milks. Powder specification No. 11 was significantly sweeter than other powders. On the other hand, specifications No. 13 and 23 were considered significantly less sweet than other powders. Specification No. 11 was a 28% fat powder containing no additional vitamins and minerals. Its high fat content may have influenced other 'basic' notes in the flavour, such as sweetness. This powder was processed only once during the season. More data would be required to be sure that this is a true specification effect and not confused by factory or month effects. Both powder specification Nos. 13 and 23 contained high additions of vitamins. Specification No. 23, in particular, with its high levels of vitamins and iron was significantly less intense in these 'basic' attributes.

Factory and specification effects on the sweetness of reconstituted milks were again highly significant in data from the 1980/81 season (see Appendix 27). The adjusted means for the five factories indicated that powders from Factory No. 3 were slightly sweeter and powders from Factory No. 4 less sweet than those from other factories. These factory effects will undoubtedly have been influenced by the powders processed in individual factories, due to confounding of the main effects. There was also a highly significant specification effect in these data. The adjusted means indicated that powder specifications Nos. 15, 16, 21 and 22 were all slightly sweeter than other reconstituted milks. All these specification powders contained vitamins A and D. Addition of these vitamins enhanced the sweetness of the reconstituted milks. Conversely, specification No. 23 was again significantly less sweet than the other reconstituted milks.

Creaminess was another of the 'basic' flavour attributes in the reconstituted milks. During the 1979/80 season, this attribute showed highly significant (at the 0.1% level) factory and specification effects (shown in Appendix 25). Milk powders processed by Factory No. 5 were significantly creamier than other powders. This factory effect will have been influenced by the particular specification powders processed at this factory during the 1979/80 season. There was also a highly significant specification effect, some powders being significantly creamier than others. Powder specification Nos. 12, 16 and 19 were all perceived as significantly creamier than other powders. All these powders contained vitamin preparations. In these specifications, the addition of vitamins appeared to have enhanced the 'basic' notes of the whole milk powder profile. Powder specification Nos. 8, 13 and 17 were perceived as significantly less creamy. These powder specifications also contained vitamin preparations. Addition of vitamins in these particular powders made the flavour perceptibly less creamy.

Factory and specification both had a highly significant (at the 0.1% level) effect on the creaminess of reconstituted milks during the 1980/81 season (see Appendix 27). Powders produced from Factories Nos. 3 and 5 were slightly more creamy than other powders. There was also a highly significant specification effect. Powder specification Nos. 15, 16, 21 and 22 were significantly creamier than other powders. All these powders contained vitamins A and D which appeared to have enhanced the creamy flavour. On the other hand, specification No. 23 which contained both vitamins and iron was considered significantly less creamy than other reconstituted milks.

When data from the 1979/80 season for the cooked/caramelised flavour in the reconstituted milks were studied (see Appendix 25), a highly significant (at the 0.1% level) specification effect was indicated. The adjusted means indicated that specification Nos. 15 and 16 were significantly more cooked/caramelised than other powders. Data from the 1980/81 season (shown in Appendix 27) also indicated a highly significant (at the 0.1% level) specification effect. Adjusted means indicated that specification Nos. 21 and 22 were slightly less cooked/caramelised than other reconstituted milks. Both contained Vitamins A and D. However, these particular specifications were processed by one factory only and it is not possible to separate the effects of the factory regime and the effects of the vitamin addition. Specification No. 23 was perceived as very much less cooked than any other reconstituted milks.

Specification had a highly significant effect on the 'lactone-like' flavour in the reconstituted milks during the 1979/80 season (see Appendix 29). Adjusted means for the different specification powders indicated that specification Nos. 6, 8, 13 and 22 were significantly more 'lactone-like' than other reconstituted milks. All these specifications were vitaminized powders, most containing a mixture of Vitamins A and D. Analysis of data from the 1980/81 season for the same attribute also indicated a significant specification effect (shown in Appendix 31). The adjusted means showed that specification Nos. 6, 12, 15, 21 and 22 were more 'lactone-like' than other reconstituted milks. Data for both seasons showed that powders with a strong 'lactone-like' flavour were all vitamin fortified. This flavour was associated with powders containing only vitamins A and D rather than with those containing more complex vitamin preparations.

Analyses of data from both the 1979/80 and 1980/81 seasons for the 'oxidised' flavour in the reconstituted milks showed (see Appendices 29 and 31) a highly significant specification effect (at the 0.1% level). The adjusted means showed that specification Nos. 8 and 23 were significantly more 'oxidised' than other reconstituted milks. Both these specifications contained additional iron, often associated with an oxidised 'cardboard' flavour in milk products. The adjusted means for these two specifications indicated that specification No. 8 was less 'oxidised' than specification No. 23. Both these powder specifications were fortified with the same vitamin and iron preparations. Data from both seasons showed that the effects of this addition were much greater on an instantized powder (specification No. 23) than on a non-agglomerated powder (specification No. 8).

Factory and specification had significant effects on the 'feedy' flavour in the reconstituted milks during the 1979/80 season (see Appendix 29). The adjusted means for the factories showed that the flavour of powders from Factory No. 2 were significantly more feedy than those from other factories. This effect will have been influenced by the specification powders processed by Factory No. 2. It should be noted that Factory No. 2 is supplied by herds which are predominantly made up of Jersey dairy cows. Milk from this breed has been known to impart a 'feedy' note to dairy products. The adjusted means for different powders showed that specification No. 8 was significantly more 'feedy' than other reconstituted milks but significantly less 'feedy' than specification No. 23. Both these specifications contained high levels of vitamins and iron. During this first season the panel associated a 'feedy' note with some of the vitaminized powders. These attributes were re-defined before the 1980/81 dairying season. Analysis of the data from the 1980/81 dairying season for the 'feedy' note in the reconstituted milks showed no significant specification effects (see Appendix 31).

The 'tainted' characteristic in the flavour of the reconstituted milks showed a significant specification effect in data from the 1979/80 season (see Appendix 29). The adjusted means indicated that this was a negative effect, specification Nos. 12 and 15 being significantly less 'tainted' than other powders. Both these specification were vitaminized powders, characterized as having a strong 'lactone-like' flavour. Perhaps because of well-defined flavour characteristics, they were less 'tainted' (a rather ill-defined flavour characteristic) than other reconstituted milks.

Data from the 1980/81 dairying season showed that both factory and specification had a significant effect on this 'tainted' attribute (shown in Appendix 31). Powders from Factory No. 3 were significantly more 'tainted' than other powders. The adjusted means for the different powders showed that specification No. 8 was significantly more 'tainted' than other powders. This powder, which contained high levels of vitamins and iron, had already displayed distinctive flavour characteristics. Specification No. 8 was a non-agglomerated powder which was not so strongly 'oxidised' or 'vitaminized' as the instantized powder containing the same additives (specification No. 23). There were clearly other flavour characteristics in this powder which the panel had some difficulty in defining precisely.

Specification had a highly significant effect on the 'vitaminized' flavour in the reconstituted milks (see Appendix 31). The adjusted means for the different powders showed that specification Nos. 6, 8, 16 and 23 were significantly more 'vitaminized' than other reconstituted milks. Similar trends had been displayed in the aroma of the reconstituted milks. Specification Nos. 8, 16 and 23 all contained a mixture of Vitamins A, B_1, C and D which had been used to represent the typical 'vitaminized' note. Specification No 6 contained Vitamins A and D (as do many other specifications) but at a higher level than any other whole milk powders. This very high level of addition resulted in a significantly stronger 'vitaminized' flavour in the reconstituted milk.

Data from the 1980/81 season only showed a significant factory and specification effect on the 'age-related' or 'stale' flavour in the reconstituted milks (shown in Appendix 31). The adjusted means showed that powders from Factory No. 5 were significantly more 'stale' than powders from other factories. Adjusted means for the various powders indicated that the flavour of specifications No. 5 and 23 was 'staler' than other reconstituted milks. Specification No. 23, an instantized powder containing a high level of vitamins and iron, had already displayed a characteristic 'stale' aroma. This 'stale' note was characteristic of the flavour also. Specification No. 5 is a 28% fat non-agglomerated powder with no added vitamins or minerals. More data is required to be sure that this 'stale' flavour is characteristic of the powder and not due to atypical samples.

5. DISCUSSION AND CONCLUSIONS

The processing variables which appeared to have the most effect on the colour, particle size and free-flowing properties were those which changed the physical structure of the powder. The physical powder type was important in the estimation of these three attributes, whether powders were non-agglomerated, agglomerated or instantized.

Significant factory effects were generally found to result from variations in these powder types. Where a factory processed only non-agglomerated powders, the powder scores for this factory were significantly different from scores for powders from other factories. One factory did achieve a greater degree of agglomeration in its powders than any of the other participating factories. This had a significant effect on the colour, free-flowing properties and particle size of its powders. However, whether this degree of agglomeration was due to a unique drier or some other factor in the processing regime was unkown.

The sweet, buttery and cooked/caramelised notes, which made up the 'basic' profile of whole milk powders, showed significant factory effects. Powders produced by Factory No. 5 during the 1979/80 season were sweeter and more buttery than other milk powders. Powders from this factory did not stand out as clearly in data from the 1980/81 season, although powders from Factory No. 3 were slightly sweeter and more buttery than other powders. These factory effects were not consistent through the two seasons which suggests that powders from individual factories do not differ consistently one from another. These effects were undoubtedly influenced by the powder specifications individual factories processed. For example, Factory No. 3 processed more powders with no added vitamins than any other factory. These particular powders, although not significantly different from most powders, tended to be scored as slightly more sweet and buttery than other specifications. Processing a large number of these powders will have influenced the overall mean for this factory (due to confounding of the main effects). Generally, it is felt that the effects of processing conditions in different factories are not as important as the effects of seasonal changes or of the addition of vitamins and minerals.

Specification effects were also significant in the assessment of the sweet, buttery and cooked/caramelised notes in the aroma and flavour of whole milk powders. In some powders containing certain vitamin preparations, the sweet, buttery and cooked/caramelised notes were accentuated. Data from both the 1979/80 and 1980/81 seasons indicated that aroma and flavour notes were enhanced in powder specification No. 16. In other specification powders, the 'basic' or 'normal' aroma and flavour attributes were masked by the presence of other flavour notes. Powder specification No. 23 was affected in this way, especially during the 1980/81 dairying season. This powder contained a high level of vitamins and iron. These additions appear to have changed the aroma and flavour of the powder, such that the sweet, buttery and cooked/caramelised notes were no longer as intense as in other powders. The sweet, buttery and cooked/caramelised notes had been most important in characterizing changes caused by seasonal effects. These attributes were no longer so important when studying the effects which the addition of vitamins had on whole milk powders. Changes in these three attributes reflected changes occurring in other aroma and flavour characteristics.

Changes in the 'other' or 'additional' categories of aroma and flavour were very important in studying the effects which the addition of vitamins and iron had on whole milk powders. Data from these attributes showed evidence of both factory and specification effects. The factory effects in these data were not as significant nor as consistent as they had been in data for the sweet, buttery and cooked/caramelised attributes. These factory effects were undoubtedly influenced by the characteristics of particular specification powders processed in a factory.

Powders containing certain vitamin mixes were found to have distinctive aroma and flavour characteristics. These attributes were somewhat confused during the 1979/80 season, since these changes were totally unexpected. Some powders which contained Vitamins A and D were characterized as 'lactone-like'. This attribute in the aroma and flavour of whole milk powders was characteristic of certain powders containing very high levels of Vitamins A and D and instantized powders containing slightly lower levels of these vitamins. During the 1979/80 season, the distinctive aroma and flavour notes associated with the 'vitaminized' powders were included in the 'taint' category. Before the 1980/81 season began, a separate 'vitaminized' category was formed and a specification containing Vitamins A, B_1, C and D used as the standard. Powders containing this particular mixture were more 'vitaminized' than other powders, as was a powder specification containing a very high level of Vitamins A and D. Certain vitaminized powders were described as 'stale', 'tainted' and 'feedy', especially during the 1979/80 season. It was believed that the use of these terms was due, in part, to a certain amount of confusion amongst panelists when faced with these unexpected attributes in the powders. Most of these terms ceased to be significant in data from the 1980/81 season.

Two powder specifications which contained both vitamins and iron were found to be significantly more 'oxidised' than other powders (even one week after production). The intensity of this oxidation appeared to be greater in an instantized powder than in a non-agglomerated powder containing the same level of iron. During the first season, there was some confusion with these powders and they were considered 'feedy', 'stale' and 'tainted'. After the panel had re-defined their terms, these powders were characterized as 'oxidised' and 'vitaminized'.

To summarise; it was found that processing effects had a significant influence on the sensory attributes of whole milk powders. Processing effects on the physical properties of the powders were related to the physical structure of the powder, whether it was agglomerated or non-agglomerated. However, in the sensory attributes of aroma and flavour, it was found that the addition of vitamins and minerals had the most significant effect on these sensory characteristics. It was the 'other' or 'additional' attributes of aroma and flavour which were most important in describing these processing effects. A 'lactone-like' note in the aroma and flavour was associated with many powders containing Vitamins A and D. A term defined as 'vitaminized' was used by the panel to describe the typical aroma and flavour of powders containing a mixture of Vitamins A, B_1, C and D. The addition of iron was associated with a 'cardboard' oxidised note in the aroma and flavour of the reconstituted milks. The effects of these vitamin and iron additions were apparently enhanced in the instantized powders.

CHAPTER IX

EFFECT OF VITAMIN AND IRON ADDITION ON SENSORY PROPERTIES OF WHOLE MILK POWDERS

1. INTRODUCTION

It had become clear during the 1979/80 season that characteristic differences existed between different specification whole milk powders. Many of these differences appeared to be the result of vitamin and mineral addition to these whole milk powders. Powders containing vitamins and iron clearly had different aroma and flavour characteristics. Because of confounding of the main effects in the seasonal data it was not possible to say that these changes in the sensory properties were a direct result of these additives. In addition, it was impossible from these data to differentiate between changes due to the vitamins themselves, the processing conditions or a combination of both.

To establish the precise effect that these additions had on the sensory properties of whole milk powders, some controlled experimental work was carried out at the New Zealand Dairy Research Institute during the 1980/81 dairying season. The aim of this experimental work was to establish the effects that addition of a vitamin preparation and/or iron had on the aroma and flavour of whole milk powders.

A series of whole milk powders, which contained controlled levels of vitamins and iron, were dried at the New Zealand Dairy Research Institute. Vitamins and iron were added such that the highest level of addition was that found in one of the commercial powders evaluated during the 1979/80 season. This powder was chosen because it had exhibited the most marked changes in aroma and flavour of any specification powder tested during the 1979/80 season.

2. BACKGROUND TO EXPERIMENTAL WORK

Much of the documented research on the fortification of milk powder has been done on skim milk powder rather than on whole milk powder. Fortification of milk and milk products with vitamins and iron has been carried out for a number of years. When milkfat is removed from milk, the fat-soluble vitamins (including Vitamin A) are also removed. Because of this, it has become standard practice to return Vitamin A and other fat-soluble vitamins to skim milk or skim milk powder, especially when these products are fed to infants. Bauernfeind and Cort (1974) stated that one of the principal problems associated with the addition of Vitamin A to milk products was the flavour. However, they believed that by using special products prepared for the nutrification of milk, these problems had been solved.

Fortification of skim milk powder with iron has also been carried out for some years. The addition of iron has also caused some flavour problems but the use of suitable iron salts has largely overcome these. Most of the documented work on the fortification of skim milk powder has centred around the stability and availability of the vitamins and iron. However, Bauernfeind and Cort (1974) did indicate that overprocessing could lead to off-flavours.

Whole milk powders for use in infant feeding have been fortified with vitamins and iron for 30-40 years, since the production of roller-dried baby powders. Fortification of whole milk powders for general use has only been done for the last 10 years. Addition of vitamins to these powders has been done to meet customer requirements. There is little documented literature on the effect these additions of vitamins and minerals have on whole milk powders. Some work has been published on the stability and nutritional availability of such additions. As far as can be ascertained, there is no mention in the literature that these additions alter the aroma and flavour of whole milk powders.

3. METHODS

3.1 Experimental Design

During the 1979/80 season, powder specifications Nos. 8 and 23 (described in the previous chapter) had shown markedly different aroma and flavour attributes from those of other whole milk powders. Both specification powders contained the same level of vitamins and iron, one was a non-agglomerated powder the other an instantized powder. Because of the very distinctive sensory properties these two powders exhibited, it was decided to use these levels of vitamin and iron addition in the experimental powders.

Four experimental factors were studied, in a 2 x 2 x 2 x 3 factorial design. The first experimental factor was the level of vitamin preparation in the powder. This vitamin preparation, (which consisted of a mixture of Vitamins A, B_1, C and D) was added at a very low level and at the level used in making the commercial powder. The second experimental factor was the level of iron addition to the powder. The iron (in the form of ferrous ammonium citrate) was added at a very low level and the level used in commercial powders. The low level for both iron and vitamin preparation was chosen arbitrarily to give aroma and flavour characteristics which were distinct but not intense. The level chosen was 15% of the addition level for commercial powders. The third experimental factor was the position at which the vitamin preparation and iron were added to the milk. This addition is usually made pre-evaporator in most commercial powder plants. However, it has been suggested that post-evaporator addition may be a means of preventing vitamin loss in these powders. To see exactly what effect the position of addition had on the sensory properties, addition of vitamins and iron was made both pre- and post-evaporator. The fourth factor in the experiment was the powder type. It had been noted that the effects of vitamin and iron addition were different in different powder types. To study these effects further, each of the experimental runs was dried to give three distinct powder types: non-agglomerated, agglomerated and instantized powders. The concentrate for each of these experimental runs was dried in two spray driers to produce non-agglomerated and agglomerated powders. Some of the agglomerated powder was later lecithinated to produce an instantized powder. This gave a total of twenty four experimental powders processed. Table 54 indicates these four experimental factors and the levels for each factor.

Table 54 : Factors and levels for experimental work on addition of vitamins and iron to whole milk powder.

Factor	Levels		
Vitamins	Low Level		High Level
Iron	Low Level		High Level
Position for Addition	Post-evaporator		Pre-evaporator
Powder Type	Non-agglomerated	Agglomerated	Instantized

3.2 Processing of Experimental Powders

Experimental powders containing additional levels of vitamins and minerals were dried at the New Zealand Dairy Research Institute. The powders were dried during the height of the dairy season, to minimize any seasonal factors. The experiment was repeated to minimize any possible effects which the base material (the milk) had on the final product. A total of twenty four experimental powders were processed. These powders were evaluated by the panel for their sensory characteristics between 7 and 14 days after processing. In this way it was hoped to identify, in greater detail than was possible during the 1979/80 dairying season, the characteristics of powders containing added vitamins and iron.

Whole milk was obtained from the Manawatu Co-operative Dairy Company and stored in refrigerated silo tanks. The milk was separated and the cream and skim recombined to give a fat:solids-non-fat ratio of 26.5:71. The standardized milk was preheated to $100^{o}C$ by direct steam injection and held for 10s. The milk was concentrated in a Wiegand three effect falling-film evaporator (Wiegand Karlsruhe G.m.b.H., Karlsruhe, Germany). The target density of the concentrate was $1100 kgm^{-3}$ (equivalent to 48% solids at $50^{o}C$).

The vitamin preparation and the iron (in the form of ferrous ammonium citrate) were added at two different points in the system. Pre-evaporator addition was made to the feed tank for the evaporator. Post-evaporator addition was made to a balance tank located between the evaporator and the driers. Both preparations were dissolved in approximately 200 ml warm water, added to the tank and stirred vigorously.

Each batch of concentrate was divided into two portions and dried on two spray driers. The agglomerated powders were produced on a De Laval tall-form spray drier (The De Laval Separator Co., Dryer Division, USA) fitted with a pressure nozzle atomizer. The drier and the evaporator are controlled by an IBM System/7 process control computer. The concentrate was pumped to the drier by a high pressure pump at 240 l/h, giving a nominal powder production rate of 125 kg/h. The drier was operated with an inlet air temperature of 160^{o}C and an outlet temperature of 76^{o}C. The powder was discharged from the chamber at a moisture content of 5-6% on to a fluidized bed secondary drier and cooler. The fluidized bed drier was operated at inlet temperatures of 130^{o}C, 118^{o}C and 10^{o}C for the first, second and third sections respectively. Fine powder particles were removed from the chamber via a bustle and also from the fluidized bed hood space. These fine particles were then transported by pneumatic conveyor to the top of the drier and introduced close to the nozzle to agglomerate with freshly atomized droplets.

The non-agglomerated powders were dried in a pilot scale Anhydro spray drier (Anhydro A/S, Denmark) fitted with a 159 mm diameter disc atomizer. The concentrate was homogenized at 10/3.5 MPa at 50^{o}C and pumped to the drier at a feed rate of 114 l/h giving a nominal powder production of 62 kg/h. The drier was operated at an inlet temperature of 177^{o}C, an outlet temperature of 96^{o}C and a disc speed of 292s^{-1}. The powder was discharged from the base of the drier.

The instantized powders were produced by lecithinating agglomerated powders in the laboratory. A batch of agglomerated powder (of approximately 500 g) was placed in the bowl of a Model 701A Kenwood Mixer (Kenwood Peerless Pty Ltd., South Australia). The bowl was equipped with a cover to keep dust away from the powder. The powder was mixed slowly with an eccentric K-beater while a measured quantity of Centrolene S (Central Soya, Chicago, USA)/anhydrous milkfat mixture was sprayed from a pneumatic atomizing nozzle (chromatography spray) through a small hole in the cover. Lecithin and anhydrous milkfat were added in 2:1 proportions at a 0.5% rate of addition (to give 0.2% lecithin in the final product). The powder was then transferred to a laboratory fluidized bed drier (Glatt, Haltingen-Binzen/Baden, Germany) and heated with air, at an inlet temperature of 80^{o}C, for 10 minutes.

3.3 Methods of Statistical Analysis

Analysis of the experimental data was done using a DSIR Stats Pac program called 'Factl' (Applied Mathematics Division, DSIR, Palmerston North). This program is designed specifically for full factorial designs with even numbers of sub-samples. Data from each sensory attribute were analysed separately to find the significance of the main effects and the first order interactions.

4. EFFECTS OF VITAMIN AND IRON ADDITION ON THE SENSORY PROPERTIES OF WHOLE MILK POWDERS

The twenty four experimental whole milk powders containing controlled levels of vitamins and iron were evaluated by the panel for sensory attributes of aroma and flavour. Data from each of these sensory attributes were analysed separately to find factors responsible for changes in the aroma and flavour. A summary of results, indicating the significant factors in these changes, is given in Table 55. Each of the main experimental factors was studied in turn, to see what effect each factor had on characteristics of aroma and flavour. The significant interactions between these factors were then studied.

Table 55: Significant factors in the analyses of variance made on data from the experimental powders containing controlled levels of vitamins and iron.

	FACTOR	VITAMIN	IRON	VITAMIN X IRON	POSITION	VITAMIN X POSITION	IRON X POSITION	TYPE	VITAMIN X TYPE	IRON X TYPE	POSITION X TYPE
AROMA OF THE POWDER	Sweetness		*					*			
	Butteriness		*		*			*			
	Cooked/Caramelised										
	Lactone										
	Oxidised							*			
	Feedy										
	Vitaminized										
	Taint	*									
	Age-Related										
AROMA OF THE RECONSTITUTED MILK	Sweetness		***					***		***	
	Butteriness		***					***		**	
	Cooked/Caramelised							***		**	*
	Lactone		*				*	*			
	Oxidised		***					***		***	
	Feedy							*			
	Vitaminized	***	*					***		***	*
	Taint										
	Age-Related										
FLAVOUR OF THE RECONSTITUTED MILK	Sweetness		***					***		*	
	Creaminess	*	***					***		*	
	Cooked/Caramelised	*						***		*	
	Lactone	***	*					***			
	Oxidised		***					***		*	*
	Feedy										
	Vitaminized	***						***			*
	Taint										
	Age-Related										

4.1 Effect of Vitamin Addition

The results showed that the addition of a vitamin preparation containing Vitamins A, B_1, C and D, had a highly significant effect on certain attributes of aroma and flavour (see Table 55). In the aroma of the powder, the level of vitamin addition had a significant effect (at the 5% level) on the 'taint' characteristic only (see Appendix 34). The means showed that as the level of vitamin addition increased, the intensity of this 'taint' characteristic decreased. Scores for the two levels of vitamin addition were very low and differences appeared to be quite small. The level of vitamin addition also had a highly significant (at the 0.1% level) effect on the 'vitaminized' aroma in the reconstituted milks (see Appendix 36). As the level of vitamin addition increased, the intensity of this note increased.

Data for creamy and cooked/caramelised flavour notes in whole milk powders showed that vitamin addition had a significant effect on these attributes also (shown in Appendix 37). Means for these two attributes showed that this was an inverse relationship. As the level of vitamin addition increased, the intensity of these flavours decreased. Data for the 'vitaminized' flavour also showed that the level of vitamin addition had a highly significant (at the 0.1% level) effect on this attribute (see Appendix 28). As the level of vitamin addition increased, the intensity of this 'vitaminized' flavour in the reconstituted milks increased. This established that addition of a vitamin preparation did change the aroma and flavour of the whole milk powders significantly. This change was a distinctive one which the panel defined as a change in the 'vitaminized' aroma and flavour of reconstituted milks.

4.2 Effect of Iron Addition

The addition of iron to the powders also had a highly significant effect on many aroma and flavour attributes (see Table 55). Data for sweet and buttery notes in the aroma of the experimental whole milk powders (see Appendix 33) showed that iron addition had a significant (at the 5% level) effect on these attributes. Iron addition also had a highly significant (at the 0.1% level) effect on the sweet and buttery notes in the aroma of the reconstituted milks (see Appendix 35). In both the aroma of the powders and of the reconstituted milks, the intensity of these characteristics decreased as the level of iron in the powder increased. The level of iron addition had a similar effect on the 'lactone-like' note in the aroma of the reconstituted milks (see Appendix 36). As the level of iron addition increased, the 'lactone-like' note in the aroma decreased. It appeared that as other aroma characteristics became dominant, this rather mild characteristic became 'weaker'.

The 'oxidised' aroma in the milks was highly significantly affected (at the 0.1% level) by the level of iron addition (see Appendix 36). As the level of iron in the powder increased, the 'oxidised' note in the aroma of the reconstituted milks increased. Addition of iron to the powders also increased the 'vitaminized' aroma in the reconstituted milks (see Appendix 36). Addition of iron to these powders clearly caused a distinct 'oxidised' note and also intensified the 'vitaminized' note in the aroma. It is not known precisely what compounds make up this 'vitaminized' characteristic. It is possible that some of them could be breakdown product of the vitamins themselves. Addition of iron may catalyse the breakdown of these compounds causing a more intense 'vitaminized' note.

The level of iron addition also had a highly significant (at the 0.1% level) effect on the sweet and creamy flavours in the reconstituted milks (see Appendix 37). As the level of iron addition increased, the intensity of these flavours decreased. Data for the 'lactone-like' flavour in the reconstituted milks showed that iron addition had a significant (at the 5% level) effect on this attribute (see Appendix 38). This effect was similar to that on the sweet and creamy flavours. As the level of iron addition increased, the 'lactone-like' note decreased in intensity. Addition of iron has been associated with an 'oxidised' flavour in dairy products and in these data the level of iron addition had a highly significant (at the 0.1% level) effect on the 'oxidised' flavour in the reconstituted milks (see Appendix 38). As the level of iron in the powder increased, the intensity of the 'oxidised' flavour increased.

4.3 Effect of Position of Addition

The position at which the vitamin and mineral addition was made had a significant effect (at the 5% level) on the butteriness of the powder aroma only (see Appendix 33). Powders in which vitamin and iron addition was post-evaporator were significantly more buttery than those in which addition was pre-evaporator. Pre-evaporator addition of iron caused a stronger 'oxidised' note than post-evaporator addition. Increases in attributes (such as the 'oxidised' note) with pre-evaporator addition of iron may be the reason for this significant position effect in the butteriness of the powder aroma. As other attributes became stronger, the 'basic' buttery note in the profile was masked.

4.4 Effect of Powder Type

The experimental data showed that the powder types had a highly significant effect on the aroma and flavour of the experimental whole milk powders. Powder type had a significant (at the 5% level) effect on both the sweet and buttery notes in the powder aroma (see Appendix 33). The means indicated that sweetness and butteriness were highest in non-agglomerated powders and lowest in instantized powders. Data for the 'oxidised' note in the powder aroma showed the reverse effect (see Appendix 34). The powder type again had a significant (at the 5% level) effect on this attribute. The means showed that non-agglomerated powders were significantly more oxidised than instantized powders. Mean scores for all these powders were very low and the differences between samples were small.

The powder type also had a highly significant effect (at the 0.1% level) on the sweet, buttery and cooked/caramelised notes in the aroma of the reconstituted milks (see Appendix 35). Each of these characteristics was significantly 'weaker' in the instantized powders than in either non-agglomerated or agglomerated powders. Many aroma and flavour attributes were found to be much stronger in instantized powders than in either non-agglomerated or agglomerated powders. The sweet and buttery notes were no longer perceptible as other attributes became dominant.

Data for the 'lactone-like' aroma in the reconstituted milks also showed a significant (at the 5% level) powder type effect (shown in Appendix 36). The means showed that agglomerated powders had the strongest and instantized powders the weakest 'lactone-like' aroma. This mild attribute was rather easily 'masked' by other aroma characteristics. In instantized powders, which had a more dominating aroma, this characteristic was not so intense. Data for the 'oxidised' aroma in the reconstituted milks showed the opposite effect. Powder type again had a highly significant (at the 0.1% level) effect. The means showed that instantized powders had a significantly more 'oxidised' aroma than either non-agglomerated or agglomerated powders.

There were also significant differences between the powder types in the 'feedy' aroma in the reconstituted milks (see Appendix 36). Non-agglomerated and agglomerated powders were significantly more 'feedy' than instantized powders. The 'feedy' note was associated with the 'basic' or 'normal' notes in whole milk powders. In non-agglomerated and agglomerated powders, these 'basic' notes were more intense than in the instantized powders. However, mean scores for this attribute were all very low and differences were rather small. Data for the 'vitaminized' aroma in the reconstituted milks showed that differences between powder types were highly significant (see Appendix 36). Instantized powders were significantly more 'vitaminized' than either non-agglomerated or agglomerated powders. Panelists had used an instantized powder as the standard 'vitaminized' whole milk powder. Some of its distinctive properties would appear to result from powder type rather than from vitamin addition.

As was found in data for the aroma, powder type had a highly significant (at the 0.1% level) effect on sweet, creamy and cooked/caramelised flavours in the reconstituted milks (see Appendix 37). The means showed that instantized powders were less sweet, creamy and cooked/caramelised than either non-agglomerated or agglomerated powders. Data from the 'lactone-like' flavour in the reconstituted milks (see Appendix 38) showed a similar trend. The means showed that instantized powders were significantly less 'lactone-like' than either non-agglomerated or agglomerated powders. As other flavours, such as 'oxidised', became more dominant in instantized powders, the rather mild 'lactone-like' flavour decreased in intensity.

The 'oxidised' flavour in the reconstituted milk was significantly (at the 0.1% level) affected by the powder type (see Appendix 38). The instantized powders were all significantly more 'oxidised' than either non-agglomerated or agglomerated powders. Data for the 'vitaminized' flavour in the reconstituted milks (see Appendix 38) showed a similar effect. In these data also, instantized powders were significantly more 'vitaminized' than the other powder types.

It had been observed during the seasonal work that the effect of certain vitamin and iron additions was much greater in instantized powders than in other powder types. Baldwin and Humphries (1976) showed that lecithination of whole milk powders (to produce instantized powders) did not significantly change the flavour of whole milk powders. When data from the first experimental powders were analysed, it was clear that the instantized powders were significantly different from other powder types. To clarify these apparent anomalies, four extra experimental powders were processed when the experimental design was repeated. These four powders contained no additional vitamins and iron (added pre- and post-evaporator). Two powders were instantized, two were non-agglomerated powders. Analysis of data from these four extra powders was done separately and showed a significant difference (at the 5% level) only in the buttery note of the powder aroma. The instantized powders were considered to be slightly less buttery than non-lecithinated powders. These analyses clearly demonstrated that the very marked differences between instantized powders and other powder types occurred only in the presence of a vitamin preparation and iron.

4.5 Iron x Position of Addition Interaction

Data for the 'lactone-like' aroma in the reconstituted milks showed a significant (at the 5% level) interaction between the level of iron addition and the position of this addition (pre- or post-evaporator). When iron addition was made post-evaporator, the intensity of the 'lactone-like' note increased with increasing iron in the powders. However, when addition was pre-evaporator, this note decreased with increasing iron addition. Addition of iron pre-evaporator tended to give a stronger 'oxidised' note than post-evaporator addition. It is possible that as this oxidised note became more dominant, the mild 'lactone-like' note was 'masked'.

4.6 Iron x Powder Type Interactions

There were a number of highly significant interactions between the level of iron addition and the powder type. Experimental data for sweet, buttery and cooked/caramelised notes in the aroma of the reconstituted milks showed (see Appendix 35) significant iron by powder type interactions. The interaction means for all three aroma characteristics showed similar trends. At the high level of iron addition, instantized powders were very much less sweet, buttery and cooked/caramelised than either non-agglomerated or agglomerated powders.

Data for 'oxidised' and 'vitaminized' notes in the aroma of reconstituted milks (see Appendix 36) showed highly significant (at the 0.1% level) interactions between the level of iron addition and the three powder types. The interaction means showed that the differences between instantized powders and other powder types were much greater at the high than at the low level of addition. Instantized powders were all more 'oxidised' and 'vitaminized' than other powder types. However, at the high level of iron addition the differences in intensity between instantized powders and other powders were much greater.

There were also significant interactions between the level of iron addition and powder type in data for sweet, creamy and cooked/caramelised flavours in the reconstituted milks (see Appendix 37). The means showed similar trends in each case. Instantized powders were much less sweet, creamy and cooked/caramelised than other powders at the high than at the low level of addition. As in data for the aroma, there was a significant interaction between level of iron addition and powder type in the 'oxidised' flavour of the reconstituted milks (see Appendix 38). Means for this interaction indicated that differences between powder types were much greater at the higher level of iron addition than at the lower level. Again, instantized powders were significantly more 'oxidised' than other powder types but differences were much greater at the high level of iron addition.

4.7 Position of Addition x Powder Type Interactions

There were several significant interactions between the position at which the vitamin preparation and iron were added and the powder type. Data for the cooked/caramelised note in the aroma of the reconstituted milks (see Appendix 35) showed a significant interaction between these two factors. The means indicated that instantized powders were very much less cooked when vitamin and iron addition was made post-evaporator rather than pre-evaporator. Analysis of data for the 'vitaminized' note in both aroma and flavour of reconstituted milks also showed significant interactions between the position of addition and powder type (see Appendices 36 and 38). The interaction means for both attributes showed similar trends. When addition of the vitamins and iron was made post-evaporator, the instantized powders were significantly more 'vitaminized' than when addition was made pre-evaporator. These significant interactions may reflect other changes in these instantized powders. Instantized powders in which addition was post-evaporator tended to be less 'oxidised'. It is possible that when addition was post-evaporator and the 'oxidised' note was weaker, the less dominant 'vitaminized' note was more readily perceived by the panel.

There was a significant interaction between the position of the vitamin and iron addition and the powder type in data for the 'oxidised' flavour in the reconstituted milks (see Appendix 38). The means showed that differences between the instantized and other powders were much greater when addition was pre-evaporator than when it was post-evaporator. All instantized powders were sigificantly more 'oxidised' than the other powder types. However, the differences were greater when addition was pre-evaporator. It has been suggested that when addition is pre-evaporator it allows a longer period in which the iron can react in the milk prior to drying. It was clear from this data that this pre-evaporator addition does make a significant difference but only in the instantized powders.

5. DISCUSSION AND CONCLUSIONS

Evaluation of some experimental powders containing controlled levels of vitamin and iron showed highly significant effects due to these processing variables. The level of iron and vitamin addition had very significant effects on the sweet, buttery and cooked/caramelised notes in the aroma and flavour of the whole milk powders. There was an inverse relationship between the level of vitamin and iron addition and the intensity of these three attributes. As other aroma and flavour characteristics became more dominant, these 'basic' attributes decreased in intensity. The gross composition of these 'vitaminized' milk powders was similar to powders containing no vitamins. There is no reason to believe that drastic changes had occurred in the components which give milk powder its characteristic aroma and flavour. Consequently, it was believed that the mild 'basic' notes of the profile were 'masked' by other more dominant aroma and flavour attributes.

The addition of iron had a highly significant effect on both aroma and flavour. In particular, the addition of iron was associated with an oxidised 'cardboard' aroma and flavour characteristic. This oxidised note was not the classic 'tallow' note found in very old, oxidised milkfat. Instead it was the 'cardboard' flavour often associated with metal catalysed oxidation in milk. Addition of the vitamin preparation was associated with an increase in the 'lactone-like' and the 'vitaminized' characteristics in the aroma and flavour of the reconstituted milks. The 'lactone-like' note was a sweet, perfumy and often 'coconutty' characteristic. Although not exactly the same note found in whole milk powders high in lactones, it was very similar and described as such. During the 1979/80 and 1980/81 seasons, this note was associated with certain powders containing Vitamins A and D. In the experimental powders, it was shown to be associated with increases in the level of vitamin addition. However, the intensity of this characteristic decreased as iron addition increased. This rather mild 'lactone-like' characteristic was 'masked' as the 'oxidised' characterstics became more dominant with increasing levels of iron.

High levels of vitamin addition were also associated with an increase in the 'vitaminized' characteristic . This 'vitaminized' attribute had been called 'oily', 'fishy' and 'haliborange' by the panel. Although some of these descriptions are often used for oxidised flavours, panelists were adamant that this sensory characteristic could not be categorised as 'oxidised'. Other descriptions used for the 'vitaminized' powders were 'grassy', 'mealy', 'beany' and 'legumey'. The association of these particular characteristics is thought to arise out of a powder type effect which had been highly significant in the experimental powders. The powder used to define the 'vitaminized' note in whole milk powders during the 1980/81 season was a lecithinated or instantized powder (containing approximately 0.2% soybean lecithin). Data from the experimental powders showed that in these instantized powder the 'vitaminized' note was very much stronger than in the other powder types. Litman and Numrych (1978) have described the soybean reversion flavour (which occurs on oxidation of soybean products) as 'beany, buttery, painty, fishy, grassy or hay like'. It would appear that some of the aroma and flavour characteristics associated with 'vitaminized' powders are possibly caused by oxidation of the soybean lecithin.

The powder type had a highly significant effect on the aroma and flavour characteristics. The effects of vitamin and iron addition were generally very much stronger in the instantized powders than in either the non-agglomerated or agglomerated powders. Baldwin and Humphries (1976) have shown that lecithination does not significantly change the flavour of whole milk powders. Experimental powders which contained no additional vitamins and minerals confirmed this work. However the effect of lecithination in the presence of other additives had not previously been studied. The experimental data showed clearly that in the presence of a vitamin preparation and added iron, the instantized powders displayed much more intense aroma and flavour characteristics than any of the other powders.

The position of vitamin and iron addition did have some effect on the aroma and flavour of whole milk powders. When iron was added pre-evaporator, the 'oxidised' characteristics in the aroma and flavour tended to be stronger than when addition was post-evaporator. The 'lactone-like' and 'vitaminized' notes tended to be stronger when addition was post-evaporator. These position effects had less effect on the powders than the vitamin and iron addition or the different powder types. It was concluded that the addition of vitamins and iron changed the aroma and flavour characteristics of whole milk powders quite markedly. These changes were much greater in instantized powders than in either non-agglomerated or agglomerated powders.

CHAPTER X

DISCUSSION AND CONCLUSIONS

A sensory profile was successfully established which gave a comprehensive description of the sensory properties of New Zealand whole milk powders. This method of evaluation took into account all the sensory properties which the panel thought a consumer might evaluate. It was possible to obtain a detailed description of the sensory attributes of a specific powder using thirty two descriptors of appearance, aroma, flavour and texture.

A detailed sensory profile had not been previously established for whole milk powder and it was necessary to establish the most suitable scaling method for use with this profile. A 0-10 linear scale, a semi-structured linear scale and magnitude estimation scaling were all used in association with the sensory profile. Despite the fact that magnitude estimation had been the choice of many sensory workers in recent years, in this particular project it was the least sensitive sensory scale and the most difficult to use. The semi-structured linear scale was easy to use but not very effective at differentiating between samples. The 0-10 linear scale was both easy to use and effective in differentiating between samples.

The comparison of the three sensory scales made in the present study showed that care should be taken to avoid the use of 'popular' or 'fashionable' sensory scales, when they are not appropriate for the work being undertaken. A sensory scale should be chosen which is the most suitable for the work in progress. Where possible, it is believed that a trial comparision between scales should be made. Magnitude estimation scaling has provided a very powerful research tool when used in association with controlled experimental designs. From the results of the present study, magnitude estimation scaling is not a good choice of sensory scale for long term projects, such as storage trials or seasonal studies. There are many usage problems associated when this scale is used over a long period, such as 'moving baseline'. The scoring of unforeseen attributes not originally present in the standard, such as a reference milk powder, also causes problems. One of the category scales would appear to work more effectively in long term studies, despite the dependence on 'memory standards'.

This sensory profiling method could be used to relate consumer requirements with the sensory properties of a specific powder. If it is known that certain attributes are preferred in a particular marketplace, these preferences could be matched with the attributes of individual powders. For example, 'feedy' flavours are much disliked in many Asian marketplaces. Powders without these 'feedy' characteristics could be placed on such markets. The matching of market with suitable products would be aided considerably if the dairy division grading system included a simplified form of this profiling method. The present grading system uses a single score to indicate the quality of the product. Workers, such as McBride and Hall (1979) have found that single score grades do not relate well to consumer acceptance. A profiling method would not only indicate the quality of the product but also give some description of specific powder properties. It is believed that this would offer more flexibility in the evaluation of commercial milk powders than the grading system presently in use.

Relationships between certain sensory attributes in milk powders and instrumental measurements for colour and texture were also studied. It was found that measurements of colour and particle size only could be made satisfactorily by instrumental methods. If these properties are of importance to the ultimate consumer, it would be possible to determine the physical limits of a product, according to colour and particle size, which the consumer would accept. These constitute the 'tolerance limits' for that particular attribute in the product for that marketplace. Having established these 'tolerance limits' using sensory techniques, it would then be possible to monitor the product specification for these properties using instrumental measurements.

It was clear from this study that the perceived viscosity of reconstituted milks was not related to its physical viscosity. Some other chemical or physical measurement might have related closely with perceived viscosity but more study is required in this area. It is possible that perception of this property is related to mouthfeel. Factors affecting this mouthfeel may include the fat globule distribution and possibly the protein:lactose ratio, since viscosity appeared to be related to end of season effects which include changes in this ratio. No attempt was made in this study to relate flavours perceived by the panel to chemical analyses of flavour compounds. It was considered to be outside the scope of the present study to carry out detailed chemical analyses of this nature.

Seasonal changes had a highly significant effect upon the sensory properties of whole milk powder. These seasonal effects were very significant in the 'physical' properties, such as the colour of the powders and textural attributes of the reconstituted milks. In the aroma and flavour of whole milk powders, the 'basic' aroma and flavour notes of sweetness, butteriness and cooked/caramelised were most affected by season. All three attributes tended to follow similar patterns through the season. The 'other' aroma and flavour attributes, such as 'oxidised' and 'feedy', showed some slight seasonal effects but were more significantly affected by processing changes.

In addition to naturally occurring seasonal changes, different processing conditions also affected the properties of whole milk powders significantly. It was found that processing variables had a significant effect on the 'physical' attributes, such as the colour and particle size. These effects were related to the physical structure of the powder, whether it was agglomerated or non-agglomerated. The physical structure of the powder may influence consumer acceptance of properties, such as colour. The bigger the particle size, the brighter the colour appeared. Thus, agglomerated and instantized powders were very much brighter in colour than non-agglomerated powders. In countries where yellow-coloured dairy products are objectionable this should be given due consideration in the marketing of whole milk powders. If the functional properties of an agglomerated or instantized powder are required, it may be necessary to specify a seasonal period in which colour is at its lowest, so that the colour is the palest possible for these particular powder types.

Data from the commercial milk powders showed that the addition of vitamins and iron to whole milk powders caused distinctive changes in the aroma and flavour attributes. This was confirmed by data from experimental milk powders containing controlled levels of vitamins and iron. The 'other' or additional attributes of aroma and flavour were most important in describing these processing effects. A 'lactone-like' note in the aroma and flavour was associated with many powders containing Vitamins A and D. A term defined as 'vitaminized' was used by the panel to describe the typical aroma and flavour of powders containing a a mixture of Vitamins A, B_1, C and D. The addition of iron was associated with a 'cardboard' oxidised note in the aroma and flavour of reconstituted milks. The effects of these vitamin and iron additions were very much greater in the instantized powders. The greater intensity of these attributes in the lecithinated powders appeared to be associated with oxidation of the soybean lecithin. Previous workers had shown that the lecithination of whole milk powder did not alter the flavour of the powders. This is true, provided no vitamins or minerals are present. When there are additives present, lecithination has a highly significant effect on the powder which may well be important in consumer acceptance.

These data showed clearly that addition of vitamins and iron for nutritional purposes, significantly alters the sensory properties of whole milk powders. These changes will be much greater in instantized powders. Customers must clearly understand that if these processing changes are specified, there will be alterations in the sensory properties which could affect consumer acceptance of the product.

Although this study produced a great deal of information about the sensory properties of New Zealand whole milk powders, it left a number of unanswered questions. A sensory profile for New Zealand whole milk powders was established and found to work well in describing 400 commercially produced powders. However, this was not related to the needs of the ultimate consumer. This laboratory panel profile of the commercial product needs to be related to the consumer in the market place to produce relevant information for the industry. Once consumer demands can be linked to this descriptive profile, it should then be possible to match products with marketplaces in a much more efficient way than has been possible previously.

The marked effect which the addition of vitamins and minerals had on the aroma and flavour of whole milk powders was totally unexpected. As far as can be ascertained, these effects have not been reported previously. More work is required to show the precise effect which the separate vitamins have and how these effects differ in the different powder types. It is suspected that some of the so-called 'vitaminized' attributes may be associated with breakdown of the soybean lecithin in instantized powders. More work is required, both sensory and chemical, to establish whether these distinctive aroma and flavour attributes are caused by the additives themselves or their effect on the powder types.

This project showed that it was possible to define a detailed sensory profile for New Zealand whole milk powders. This profile described seasonal and processing changes in commercial whole milk powders. Knowing both the effects of seasonal and processing changes and the requirements of the marketplace, it should be possible to send products with acceptable sensory properties to a specific market. Slight modification and simplification of the profiling method could be used to match products to market requirements far more successfully than the present single score grading system.

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Appendix 1: Questionnaire used during first dairying season (semi-structured linear scale).

Sample Nos. ____________

Name ____________ Date ____________

MILK POWDER PANEL

In front of you are a number of milk powder samples. Please evaluate these for the following characteristics and indicate, with a mark, the intensity of each characteristic.

Powder Characteristics:

Colour — Creamy-white ____________ Yellowish

Free-flowing properties — Very cohesive ____________ Very free-flowing

Particle Description — Fine ____________ Granular

Aroma:

1. Sweetness — Not sweet ____________ Very sweet
2. Butteriness — Absent ____________ Very strong
3. Cooked/Caramel-ised — Absent ____________ Very strong
4. Other ________ — Absent ____________ Very strong

   ________ — Absent ____________ Very strong

   ________ — Absent ____________ Very Strong

COMMENTS:

Appendix 1 (continued)

Reconstituted Milk Characteristics

Aroma:

1. Sweetness — Not sweet ____________ Very sweet
2. Butteriness — Absent ____________ Very strong
3. Cooked/Caramel-ised — Absent ____________ Very strong
4. Other ________ — Absent ____________ Very strong

   ________ — Absent ____________ Very strong

   ________ — Absent ____________ Very strong

Flavour:

1. Sweetness — Not sweet ____________ Very sweet
2. Creaminess — Absent ____________ Very strong
3. Cooked/Caramel-ised — Absent ____________ Very strong
4. Other ________ — Absent ____________ Very strong

   ________ — Absent ____________ Very strong

   ________ — Absent ____________ Very strong

Texture:

1. Viscosity — Thin ____________ Thick
2. Astringency — Absent ____________ Very strong

COMMENTS:

Appendix 2: Questionnaire used during first dairying season (magnitude estimation scaling)

MAGNITUDE ESTIMATION SCALING

Name ________________ Date ________________

MILK POWDER PANEL

In front of you are a number of milk powder samples. Please evaluate these for the following characteristics in terms of the Reference sample which has been provided. Think in multiples, i.e. 1x, 2x, ½x, 3/4x etc.

Powder Characteristics:

	Reference	Sample Nos. ____	____	____	____
Colour (Creamy-white → Yellowish)	1	____	____	____	____
Free-flowing properties (Very cohesive → Very free-flowing)	1	____	____	____	____
Particle Description (Fine → Granular)	1	____	____	____	____

Aroma:

	Reference				
1. Sweetness (Not sweet → Very sweet)	1	____	____	____	____
2. Butteriness (Not buttery → Very buttery)	1	____	____	____	____
3. Cooked/Caramelised (Not cooked → Very cooked)	1	____	____	____	____
4. Other a. ________	____	____	____	____	____
b. ________	____	____	____	____	____
c. ________	____	____	____	____	____

COMMENTS:

Appendix 2 (continued)

Reconstituted Milk Characteristics

	Reference	Sample Nos.			
		____	____	____	____
Aroma					
1. Sweetness (Not sweet → Very sweet)	1	____	____	____	____
2. Butteriness (Absent → Very strong)	1	____	____	____	____
3. Cooked/Caramelised (Absent → Very strong)	1	____	____	____	____
4. Other a. ________	___	____	____	____	____
________	___	____	____	____	____
________	___	____	____	____	____
Flavour:					
1. Sweetness (Not sweet → Very sweet)	1	____	____	____	____
2. Creaminess (Not creamy → Very creamy)	1	____	____	____	____
3. Cooked/Caramelised (Absent → Very strong)	1	____	____	____	____
4. Other a. ________	___	____	____	____	____
________	___	____	____	____	____
________	___	____	____	____	____
Texture:					
1. Viscosity (Thin → Thick)	1	____	____	____	____
2. Astringency (Absent → Very Strong)	1	____	____	____	____

COMMENTS:

Appendix 3: Results of analyses of variance made on data (sensory and instrumental) from the 1979/80 and 1980/81 seasons for colour in whole milk powders.

SENSORY DATA

Complete Data (1979/80 Season)

SOURCE	SS	DF	MS	F
Factory	96.52	4	24.13	16.77 ***
Specification	304.78	18	16.93	11.77 ***
Month	126.95	8	15.87	11.03 ***
Lack of Fit	212.97	81	2.63	1.83 ***
Error	1431.43	995	1.44	

Non-Vitaminized Powders (1979/80 Season)

Factory	80.85	4	20.21	14.45 ***
Specification	112.47	4	28.12	20.11 ***
Month	49.13	7	7.02	5.02 ***
Lack of Fit	71.02	29	2.45	1.75 *
Error	557.96	399	1.40	

Vitaminized Powders (1979/80 Season)

Factory	59.26	4	14.81	10.11 ***
Specification	127.16	11	11.56	7.89 ***
Month	71.06	8	8.88	6.06 ***
Lack of Fit	131.12	43	3.05	2.08 ***
Error	873.47	596	1.47	

Complete Data (1980/81 Season)

Factory	10.46	4	2.61	1.68 NS
Specification	55.09	10	5.51	3.43 ***
Month	37.18	4	9.29	5.79 ***
Lack of Fit	35.03	11	3.18	1.98 *
Error	427.04	266	1.61	

INSTRUMENTAL DATA

Yellowness Index

Factory	63.41	4	15.85	7.32 ***
Specification	256.60	18	14.26	6.58 ***
Month	368.14	8	46.02	21.24 ***
Error	175.53	81	2.17	

Appendix 4: Results of analyses of variance made on sensory data from the 1979/80 season for free-flowing properties and particle size in whole milk powders.

FREE-FLOWING PROPERTIES

SOURCE	SS	DF	MS	F
Factory	72.29	4	18.20	8.16 ***
Specification	422.30	18	23.46	10.51 ***
Month	31.69	8	3.96	1.78 NS
Lack of Fit	335.86	81	4.15	1.86 ***
Error	2218.34	995	2.23	

PARTICLE SIZE

SOURCE	SS	DF	MS	F
Factory	8.60	4	2.15	1.02 NS
Specification	673.40	18	37.41	17.67 ***
Month	31.27	8	3.91	1.85 NS
Lack of Fit	204.69	81	2.53	1.19 NS
Error	2107.48	995	2.12	

Appendix 5: Results of analyses of variance made on sensory data from the 1979/80 season for viscosity in reconstituted milks.

Complete Data

SOURCE	SS	DF	MS	F
Factory	11.62	4	2.91	1.63 NS
Specification	34.39	18	1.91	1.07 NS
Month	63.25	8	7.91	4.43 ***
Lack of Fit	74.65	81	0.92	0.52 NS
Error	1776.58	995	1.79	

Non Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	9.99	4	2.50	1.43 NS
Specification	4.79	4	1.20	0.69 NS
Month	26.90	7	3.84	2.20 *
Lack of Fit	27.39	29	0.94	0.54 NS
Error	696.30	399	1.75	

Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	6.77	4	1.69	0.93 NS
Specification	19.31	11	1.76	0.97 NS
Month	41.21	8	5.15	2.84 **
Lack of Fit	42.86	43	1.00	0.55 NS
Error	1080.28	596	1.81	

Appendix 6: Results of analyses of variance made on sensory data from 1980/81 season for viscosity in reconstituted milks.

Complete Data

SOURCE	SS	DF	MS	F
Factory	24.29	4	6.07	3.73 **
Specification	35.13	14	2.51	1.54 NS
Month	80.43	8	10.05	6.17 ***
Lack of Fit	311.70	251	1.24	0.76 NS
Error	4052.87	2489	1.63	

Early Season Data

SOURCE	SS	DF	MS	F
Factory	6.21	4	1.55	1.11 NS
Specification	18.03	11	1.64	1.17 NS
Fortnight	4.15	4	1.04	0.74 NS
Lack of Fit	137.66	102	1.35	0.96 NS
Error	1536.00	1094	1.40	

Late Season Data

SOURCE	SS	DF	MS	F
Factory	18.79	4	4.70	2.49 *
Specification	9.05	13	0.70	0.37 NS
Fortnight	9.07	4	2.27	1.20 NS
Lack of Fit	121.13	100	1.21	0.64 NS
Error	2063.20	1093	1.89	

Appendix 7: Results of analyses of variance made on sensory data from the 1979/80 season for astringency in reconstituted milks.

Complete Data

SOURCE	SS	DF	MS	F
Factory	2.88	4	0.72	0.25 NS
Specification	51.78	18	2.88	0.99 NS
Month	244.24	8	30.53	10.47 ***
Lack of Fit	196.80	81	2.43	0.83 NS
Error	2902.53	995	2.92	

Non Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	2.49	4	0.62	0.23 NS
Specification	8.01	4	2.00	0.73 NS
Month	102.70	7	14.67	5.31 ***
Lack of Fit	55.68	29	1.92	0.70 NS
Error	1102.01	399	2.76	

Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	0.71	4	0.18	0.06 NS
Specification	34.42	11	3.13	1.04 NS
Month	140.98	8	17.62	5.83 ***
Lack of Fit	128.30	43	2.98	0.99 NS
Error	1800.52	596	3.02	

Appendix 8: Results of analyses of variance made on sensory data from the 1980/81 season for astringency in reconstituted milks.

Complete Data

SOURCE	SS	DF	MS	F
Factory	6.47	4	1.62	0.54 NS
Specification	26.68	14	1.91	0.64 NS
Month	188.05	8	23.51	7.83 ***
Lack of Fit	547.31	251	2.18	0.73 NS
Error	7471.11	2489	3.00	

Early Season Data

SOURCE	SS	DF	MS	F
Factory	23.83	4	5.96	2.41 *
Specification	35.92	11	3.27	1.32 NS
Fortnight	44.64	4	11.16	4.51 **
Lack of Fit	190.01	102	1.86	0.75 NS
Error	2708.78	1094	2.48	

Late Season Data

SOURCE	SS	DF	MS	F
Factory	7.27	4	1.82	0.52 NS
Specification	21.51	13	1.66	0.47 NS
Fortnight	7.69	4	1.92	0.55 NS
Lack of Fit	193.71	100	1.94	0.55 NS
Error	3838.54	1093	3.51	

Appendix 9: Results of analyses of variance made on sensory data from the 1979/80 season for the sweet, buttery and cooked/caramelised notes in the aroma of whole milk powders.

SWEETNESS

SOURCE	S	DF	MS	F
Factory	28.14	4	7.03	3.22 *
Specification	84.14	18	4.67	2.14 **
Month	90.41	8	11.30	5.17 ***
Lack of Fit	218.69	81	2.70	1.23 NS
Error	2176.57	995	2.19	

BUTTERINESS

SOURCE	S	DF	MS	F
Factory	20.48	4	5.12	1.96 NS
Specification	134.43	18	7.47	2.86 ***
Month	124.89	8	15.61	5.97 ***
Lack of Fit	321.04	81	3.96	1.52 **
Error	2603.11	995	2.62	

COOKED/CARAMELISED

SOURCE	S	DF	MS	F
Factory	7.21	4	1.80	0.88 NS
Specification	37.92	18	2.11	1.02 NS
Month	140.98	8	17.62	8.57 ***
Lack of Fit	135.25	81	1.67	0.81 NS
Error	2046.90	995	2.06	

Appendix 10: Results of analyses of variance made on sensory data from the non-vitaminized and vitaminized powders tested during the 1979/80 season for the sweet, buttery and cooked/caramelised notes in the aroma of whole milk powders.

SWEETNESS

Non-Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	32.82	4	8.21	3.77 **
Specification	33.78	4	8.45	3.88 **
Month	62.44	7	8.92	4.10 ***
Lack of Fit	71.14	29	2.45	1.13 NS
Error	867.85	399	2.18	

Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	35.42	4	8.85	4.03 **
Specification	52.44	11	4.77	2.17 *
Month	53.18	8	6.65	3.03 **
Lack of Fit	104.69	43	2.44	1.11 NS
Error	1308.72	596	2.20	

BUTTERINESS

Non-Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	16.62	4	4.16	1.61 NS
Specification	21.15	4	5.29	2.05 NS
Month	79.35	7	11.34	4.39 ***
Lack of Fit	93.10	29	3.21	1.24 NS
Error	1029.62	399	2.58	

Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	69.91	4	17.48	6.62 ***
Specification	106.34	11	9.67	3.66 ***
Month	94.50	8	11.81	4.47 ***
Lack of Fit	174.39	43	4.06	1.54 *
Error	1573.49	596	2.64	

Appendix 10 (continued)

COOKED/CARAMELISED

Non-Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	7.43	4	1.86	0.99 NS
Specification	12.78	4	3.19	1.71 NS
Month	48.68	7	6.95	3.72 ***
Lack of Fit	38.20	29	1.32	0.71 NS
Error	745.75	399	1.87	

Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	20.38	4	5.10	2.33 NS
Specification	17.40	11	1.58	0.73 NS
Month	92.29	8	11.54	5.28 ***
Lack of Fit	80.22	43	1.88	0.86 NS
Error	1301.14	596	2.18	

Appendix 11: Results of analyses of variance made on sensory data from the 1980/81 season for the sweet, buttery and cooked/caramelised notes in the aroma of whole milk powders.

SWEETNESS

SOURCE	SS	DF	MS	F
Factory	23.48	4	5.87	4.39 **
Specification	32.01	14	2.29	1.71 *
Month	50.48	8	6.31	4.71 ***
Lack of Fit	328.46	251	1.31	0.98 NS
Error	3326.72	2489	1.34	

BUTTERINESS

SOURCE	SS	DF	MS	F
Factory	38.68	4	9.67	4.76 ***
Specification	47.07	14	3.36	1.65 NS
Month	20.28	8	2.53	1.25 NS
Lack of Fit	437.68	251	1.74	0.86 NS
Error	5059.14	2489	2.03	

COOKED/CARAMELISED

SOURCE	SS	DF	MS	F
Factory	4.69	4	1.17	0.82 NS
Specification	17.37	14	1.24	0.87 NS
Month	34.44	8	4.31	3.02 **
Lack of Fit	274.91	251	1.10	0.77 NS
Error	3554.17	2489	1.43	

Appendix 12: Results of analyses of variance made on early and late season sensory data from the 1980/81 season for the sweet and cooked/caramelised notes in the aroma of whole milk powders.

SWEETNESS

Early Season Data

SOURCE	SS	DF	MS	F
Factory	16.68	4	4.17	3.25 *
Specification	29.23	11	2.66	2.07 *
Fortnight	22.69	4	5.67	4.43 **
Lack of Fit	138.51	102	1.36	1.06 NS
Error	1402.85	1094	1.28	

Late Season Data

SOURCE	SS	DF	MS	F
Factory	9.37	4	2.34	1.79 NS
Specification	34.13	13	2.63	2.01 *
Fortnight	6.93	4	1.73	1.33 NS
Lack of Fit	105.06	100	1.05	0.80 NS
Error	1429.46	1093	1.31	

COOKED/CARAMELISED

Early Season Data

SOURCE	SS	DF	MS	F
Factory	2.57	4	0.64	0.51 NS
Specification	7.21	11	0.66	0.52 NS
Fortnight	11.55	4	2.89	2.31 NS
Lack of Fit	88.79	102	0.87	0.70 NS
Error	1367.76	1094	1.25	

Late Season Data

SOURCE	SS	DF	MS	F
Factory	4.06	4	1.02	0.64 NS
Specification	16.00	13	1.23	0.77 NS
Fortnight	10.75	4	2.69	1.69 NS
Lack of Fit	140.27	100	1.40	0.88 NS
Error	1740.70	1093	1.59	

Appendix 13: Results of analyses of variance made on sensory data from the 1979/80 season for the lactone-like, oxidised, feedy, taint and age-related notes in the aroma of whole milk powders.

LACTONE-LIKE

SOURCE	SS	DF	MS	F
Factory	8.21	4	2.05	0.56 NS
Specification	50.68	18	2.82	0.77 NS
Month	83.92	8	10.49	2.88 **
Error	295.04	81	3.64	

OXIDISED

SOURCE	SS	DF	MS	F
Factory	14.21	4	3.55	0.78 NS
Specification	69.83	18	3.88	0.85 NS
Month	90.81	8	11.35	2.48 *
Error	370.89	81	4.58	

FEEDY

SOURCE	SS	DF	MS	F
Factory	21.20	4	5.30	0.75 NS
Specification	64.53	18	3.58	0.51 NS
Month	53.67	8	6.71	0.95 NS
Error	573.65	81	7.08	

TAINT

SOURCE	SS	DF	MS	F
Factory	34.21	4	8.55	0.64 NS
Specification	323.31	18	17.96	1.34 NS
Month	279.74	8	34.97	2.62 *
Error	1083.09	81	13.37	

AGE-RELATED

SOURCE	SS	DF	MS	F
Factory	30.47	4	7.62	0.58 NS
Specification	414.16	18	23.01	1.76 *
Month	285.31	8	35.66	2.73 *
Error	1057.93	81	13.06	

Appendix 14: Results of analyses of variance made on sensory data from the non-vitaminized and vitaminized powders tested during the 1979/80 season for the lactone-like, oxidised, taint and age-related notes in the aroma of whole milk powders.

LACTONE-LIKE

Non-Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	23.35	4	5.84	2.02 NS
Specification	23.61	4	5.90	2.04 NS
Month	54.89	7	7.84	2.71 *
Error	83.81	29	2.89	

Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	26.44	4	6.61	1.56 NS
Specification	54.86	11	4.99	1.18 NS
Month	47.71	8	5.96	1.41 NS
Error	181.79	43	4.23	1.41 NS

OXIDISED

Non-Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	13.27	4	3.32	0.41 NS
Specification	25.63	4	6.41	0.80 NS
Month	85.04	7	12.15	1.51 NS
Error	233.10	29	8.04	

Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	7.33	4	1.83	0.61 NS
Specification	26.96	11	2.45	0.82 NS
Month	40.65	8	5.08	1.70 NS
Error	128.32	43	2.98	

Appendix 14 (continued)

TAINT

Non-Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	30.05	4	7.51	0.43 NS
Specification	106.56	4	26.64	1.51 NS
Month	155.04	7	22.15	1.26 NS
Error	511.17	29	17.63	
Vitaminized Powders				
Factory	25.26	4	6.31	0.56 NS
Specification	139.59	11	12.69	1.12 NS
Month	211.49	8	26.44	2.33 *
Error	488.82	43	11.37	
AGE-RELATED				
Non-Vitaminized Powders				
Factory	1.37	4	0.34	0.04 NS
Specification	18.23	4	4.56	0.58 NS
Month	49.78	7	7.11	0.91 NS
Error	266.75	29	7.82	
Vitaminized Powders				
Factory	265.46	4	66.36	3.76 *
Specification	244.36	11	22.21	1.26 NS
Month	300.61	8	37.58	2.13 NS
Error	759.33	43	17.66	

Appendix 15: Results of analyses of variance made on sensory data from the 1980/81 season for the lactone-like, oxidised, feedy, vitaminized, taint and age-related notes in the aroma of whole milk powders.

LACTONE-LIKE

SENSORY	SS	DF	MS	F
Factory	2.14	4	0.53	0.40 NS
Specification	28.45	14	2.03	1.53 NS
Month	20.12	8	2.52	1.89 NS
Lack of Fit	269.47	251	1.07	0.81 NS
Error	3316.82	2489	1.33	
OXIDISED				
Factory	16.56	4	4.14	2.90 *
Specification	26.26	14	1.88	1.32 NS
Month	18.39	8	2.30	1.61 NS
Lack of Fit	367.99	251	1.47	1.03 NS
Error	3549.50	2489	1.43	
FEEDY				
Factory	7.85	4	1.96	1.71 NS
Specification	23.96	14	1.71	1.49 NS
Month	8.39	8	1.05	0.91 NS
Lack of Fit	286.58	251	1.14	0.99 NS
Error	2856.39	2489	1.15	

Appendix 15 (continued)

VITAMINIZED

SOURCE	SS	DF	MS	F
Factory	11.12	4	2.78	1.28 NS
Specification	41.99	14	2.99	1.38 NS
Month	45.52	8	5.69	2.61 **
Lack of Fit	451.49	251	1.80	0.83 NS
Error	5421.23	2489	2.18	

TAINT

SOURCE	SS	DF	MS	F
Factory	5.41	4	1.35	1.28 NS
Specification	45.61	14	3.26	3.08 ***
Month	18.27	8	2.28	2.16 *
Lack of Fit	306.89	251	1.22	1.16 NS
Error	2633.53	2489	1.06	

AGE-RELATED

SOURCE	SS	DF	MS	F
Factory	4.83	4	1.21	1.51 NS
Specification	26.42	14	1.89	2.36 **
Month	11.28	8	1.41	1.76 NS
Lack of Fit	188.69	251	0.75	0.94 NS
Error	1988.28	2489	0.80	

Appendix 16: Results of analyses of variance made on early and late season sensory data from the 1980/81 season for the vitaminized and taint notes in the aroma of whole milk powders.

VITAMINIZED

Early Season Data

SOURCE	SS	DF	MS	F
Factory	14.82	4	3.71	1.46 NS
Specification	40.24	11	3.66	1.44 NS
Fortnight	8.88	4	2.22	0.88 NS
Lack of Fit	220.52	102	2.16	0.85 NS
Error	2776.14	1094	2.54	
Late Season Data				
Factory	5.87	4	1.47	0.78 NS
Specification	39.25	13	3.02	1.61 NS
Fortnight	9.09	4	2.27	1.21 NS
Lack of Fit	115.39	100	1.15	0.61 NS
Error	2056.22	1093	1.88	

TAINT

Early Season Data

SOURCE	SS	DF	MS	F
Factory	2.38	4	0.59	0.55 NS
Specification	17.08	11	1.55	1.43 NS
Fortnight	13.67	4	3.42	3.15 *
Lack of Fit	126.63	102	1.24	1.15 NS
Error	1185.40	1094	1.08	
Late Season Data				
Factory	10.32	4	2.58	2.41 *
Specification	29.73	13	2.29	2.14 *
Fortnight	3.33	4	0.83	0.78 NS
Lack of Fit	121.33	100	1.21	1.13 NS
Error	1168.56	1093	1.07	

Appendix 17: Results of analyses of variance made on sensory data from the 1979/80 season for the sweet, buttery and cooked/caramelised notes in the aroma of the reconstituted milks.

SWEETNESS

SOURCE	SS	DF	MS	F
Factory	8.98	4	2.25	1.05 NS
Specification	83.95	18	4.66	2.18 **
Month	85.75	8	10.72	5.02 ***
Lack of Fit	127.30	81	1.57	0.74 NS
Error	2125.01	995	2.14	

BUTTERINESS

SOURCE	SS	DF	MS	F
Factory	5.52	4	1.38	0.72 NS
Specification	41.04	18	2.28	1.20 NS
Month	53.94	8	6.74	3.54 ***
Lack of Fit	119.27	81	1.47	0.77 NS
Error	1896.89	995	1.91	

COOKED/CARAMELISED

SOURCE	SS	DF	MS	F
Factory	8.21	4	2.05	0.76 NS
Specification	111.12	18	6.17	2.29 **
Month	98.76	8	12.35	4.58 ***
Lack of Fit	183.64	81	2.27	0.84 NS
Error	2682.67	995	2.70	

Appendix 18: Results of analyses of variance made on sensory data from the non-vitaminized and vitaminzed powders tested during the 1979/80 season for the sweet, buttery and cooked/ caramelised notes in the aroma of the reconstituted milks.

SWEETNESS

Non-Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	10.00	4	2.50	1.23 NS
Specification	8.53	4	2.13	1.05 NS
Month	46.02	7	6.57	3.23 **
Lack of Fit	46.56	29	1.61	0.79 NS
Error	812.05	399	2.04	

Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	1.15	4	0.29	0.13 NS
Specification	56.02	11	5.09	2.31 **
Month	45.99	8	5.75	2.61 **
Lack of Fit	66.81	43	1.55	0.71 NS
Error	1312.97	596	2.20	

BUTTERINESS

Non-Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	6.91	4	1.73	0.94 NS
Specification	6.72	4	1.68	0.92 NS
Month	48.20	7	6.89	3.76 ***
Lack of Fit	35.63	29	1.23	0.67 NS
Error	730.99	399	1.83	

Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	3.49	4	0.87	0.45 NS
Specification	24.21	11	2.20	1.12 NS
Month	19.04	8	2.38	1.22 NS
Lack of Fit	69.69	43	1.62	0.83 NS
Error	1165.90	596	1.96	

Appendix 18 (continued)

COOKED/CARAMELISED

Non-Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	8.77	4	2.19	0.81 NS
Specification	9.11	4	2.28	0.84 NS
Month	62.80	7	8.97	3.29 **
Lack of Fit	47.58	29	1.64	0.60 NS
Error	1086.72	399	2.72	

Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	8.07	4	2.02	0.75 NS
Specification	102.06	11	9.28	3.47 ***
Month	72.02	8	9.00	3.36 ***
Lack of Fit	112.55	43	2.62	0.98 NS
Error	1595.94	596	2.68	

Appendix 19: Results of analyses of variance made on sensory data from the 1980/81 season for the sweet, buttery and cooked/caramelised notes in the aroma of the reconstituted milks.

SWEETNESS

SOURCE	SS	DF	MS	F
Factory	5.66	4	1.42	1.11 NS
Specification	166.30	14	11.88	9.29 ***
Month	62.05	8	7.76	6.07 ***
Lack of Fit	280.14	251	1.12	0.87 NS
Error	3138.40	2489	1.28	

BUTTERINESS

SOURCE	SS	DF	MS	F
Factory	5.63	4	1.41	1.09 NS
Specification	87.87	14	6.28	4.88 ***
Month	47.70	8	5.96	4.64 ***
Lack of Fit	200.26	251	0.80	0.62 NS
Error	3200.16	2489	1.29	

COOKED/CARAMELISED

SOURCE	SS	DF	MS	F
Factory	6.94	4	1.74	1.00 NS
Specification	168.28	14	12.02	6.91 ***
Month	21.36	8	2.67	1.54 NS
Lack of Fit	339.08	251	1.35	0.78 NS
Error	4327.82	2489	1.74	

Appendix 20: Results of analyses of variance made on early and late season sensory data from the 1980/81 season for the sweet and buttery notes in the aroma of the reconstituted milks.

SWEETNESS

Early Season Data

SOURCE	SS	DF	MS	F
Factory	1.98	4	0.49	0.38 NS
Specification	132.85	11	12.08	9.28 ***
Fortnight	1.35	4	0.34	0.26 NS
Lack of Fit	135.16	102	1.33	1.02 NS
Error	1424.58	1094	1.30	

Late Season Data

SOURCE	SS	DF	MS	F
Factory	4.80	4	1.20	0.96 NS
Specification	17.32	13	1.33	1.06 NS
Fortnight	17.59	4	4.40	3.51 **
Lack of Fit	82.15	100	0.82	0.66 NS
Error	1370.33	1093	1.25	

BUTTERINESS

Early Season Data

SOURCE	SS	DF	MS	F
Factory	0.89	4	0.22	0.19 NS
Specification	61.63	11	5.60	4.76 ***
Fortnight	0.77	4	0.19	0.16 NS
Lack of Fit	79.51	102	0.78	0.66 NS
Error	1288.80	1094	1.18	

Late Season Data

SOURCE	SS	DF	MS	F
Factory	5.21	4	1.30	0.92 NS
Specification	20.16	13	1.55	1.10 NS
Fortnight	11.55	4	2.89	2.05 NS
Lack of Fit	85.27	100	0.85	0.61 NS
Error	1540.92	1093	1.41	

Appendix 21: Results of analyses of variance made on sensory data from the 1979/80 season for the lactone-like, oxidised, feedy, taint and age-related notes in the aroma of the reconstituted milks.

LACTONE-LIKE

SOURCE	SS	DF	MS	F
Factory	57.46	4	14.37	0.82 NS
Specification	901.30	18	50.07	2.87 ***
Month	180.99	8	22.62	1.30 NS
Error	1414.82	81	17.47	

OXIDISED

SOURCE	SS	DF	MS	F
Factory	4.90	4	1.22	0.29 NS
Specification	172.86	18	9.60	2.27 **
Month	118.89	8	14.86	3.51 **
Error	342.73	81	4.23	

FEEDY

SOURCE	SS	DF	MS	F
Factory	513.01	4	128.25	5.65 ***
Specification	1012.14	18	56.23	2.48 **
Month	529.31	8	66.16	2.92 **
Error	1837.68	81	22.69	

TAINT

SOURCE	SS	DF	MS	F
Factory	48.60	4	12.15	1.25 NS
Specification	490.22	18	27.23	2.81 ***
Month	35.94	8	4.49	0.46 NS
Error	785.09	81	9.69	

AGE-RELATED

SOURCE	SS	DF	MS	F
Factory	3.00	4	0.75	0.34 NS
Specification	80.48	18	4.47	2.01 *
Month	11.19	8	1.40	0.63 NS
Error	180.17	81	2.22	

Appendix 22: Results of analyses of variance made on sensory data from the non-vitaminized and vitaminized powders testing during the 1979/80 season for the oxidised and feedy notes in the aroma of the reconstituted milks

OXIDISED

Non-Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	32.77	4	8.19	3.24 *
Specification	29.96	4	7.49	2.97 *
Month	31.74	7	4.53	1.80 NS
Error	73.24	29	2.53	

Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	12.39	4	3.09	0.58 NS
Specification	173.58	11	15.69	2.93 **
Month	96.36	8	12.04	2.25 *
Error	230.25	43	5.35	

FEEDY

Non-Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	819.53	4	204.88	7.62 ***
Specification	807.99	4	201.99	7.51 ***
Month	206.20	7	29.46	1.09 NS
Error	780.23	29	26.90	

Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	23.47	4	5.87	0.43 NS
Specification	247.59	11	22.51	1.66 NS
Month	213.68	8	26.71	1.97 NS
Error	581.83	43	13.53	

Appendix 23: Results of analyses of variance made on sensory data from the 1980/81 season for the lactone-like, oxidised, feedy, vitaminized, taint and age-related notes in the aroma of the reconstituted milks.

LACTONE-LIKE

SOURCE	SS	DF	MS	F
Factory	4.44	4	1.11	0.74 NS
Specification	46.22	14	3.30	2.19 **
Month	29.15	8	3.64	2.42 *
Lack of Fit	372.08	251	1.48	0.99 NS
Error	3741.31	2489	1.50	

OXIDISED

SOURCE	SS	DF	MS	F
Factory	1.34	4	0.33	0.33 NS
Specification	487.69	14	34.84	34.59 ***
Month	8.16	8	1.02	1.01 NS
Lack of Fit	217.59	251	0.87	0.86 NS
Error	2506.41	2489	1.01	

FEEDY

SOURCE	SS	DF	MS	F
Factory	6.71	4	1.68	0.60 NS
Specification	49.77	14	3.55	1.27 NS
Month	40.29	8	5.04	1.79 NS
Lack of Fit	451.05	251	1.80	0.64 NS
Error	6991.66	2489	2.81	

Appendix 23 (continued)

VITAMINIZED

SOURCE	SS	DF	MS	F
Factory	24.68	4	6.17	1.98 NS
Specification	559.79	14	39.98	12.82 ***
Month	39.28	8	4.91	1.57 NS
Lack of Fit	702.80	251	2.80	0.90 NS
Error	7763.54	2489	3.12	

TAINT

SOURCE	SS	DF	MS	F
Factory	1.67	4	0.42	0.95 NS
Specification	17.99	14	1.28	2.94 ***
Month	3.53	8	0.44	1.01 NS
Lack of Fit	85.96	251	0.34	0.78 NS
Error	1087.39	2489	0.44	

AGE-RELATED

SOURCE	SS	DF	MS	F
Factory	0.25	4	0.06	0.69 NS
Specification	3.59	14	0.26	2.88 ***
Month	0.84	8	0.11	1.18 NS
Lack of Fit	19.66	251	0.08	0.88 NS
Error	221.50	2489	0.09	

Appendix 24: Results of analyses of variance made on early and late season sensory data for the lactone-like note in the aroma of the reconstituted milks.

Early Season Data

SOURCE	SS	DF	MS	F
Factory	1.46	4	0.36	0.19 NS
Specification	25.34	11	2.30	1.21 NS
Fortnight	4.50	4	1.13	0.59 NS
Lack of Fit	221.55	102	2.17	1.14 NS
Error	2082.89	1094	1.90	

Late Season Data

SOURCE	SS	DF	MS	F
Factory	6.01	4	1.50	1.36 NS
Specification	19.03	13	1.46	1.32 NS
Fortnight	4.06	4	1.01	0.92 NS
Lack of Fit	72.94	100	0.73	0.66 NS
Error	1209.17	1093	1.11	

Appendix 25: Results of analyses of variance made on sensory data from the 1979/80 season for the sweet, creamy and cooked/caramelised notes in the flavour of reconstituted milks.

SWEETNESS

SOURCE	SS	DF	MS	F
Factory	35.15	4	8.79	3.28 *
Specification	93.48	18	5.19	1.94 *
Month	81.56	8	10.20	3.81 ***
Lack of Fit	171.08	81	2.11	0.79 NS
Error	2665.04	995	2.68	

CREAMINESS

SOURCE	SS	DF	MS	F
Factory	43.22	4	10.81	5.45 ***
Specification	94.59	18	5.26	2.65 ***
Month	78.98	8	9.87	4.98 ***
Lack of Fit	124.77	81	1.54	0.78 NS
Error	1971.80	995	1.98	

COOKED/CARAMELISED

SOURCE	SS	DF	MS	F
Factory	20.09	4	5.02	1.87 NS
Specification	118.36	18	6.58	2.44 ***
Month	144.45	8	18.06	6.71 ***
Lack of Fit	241.84	81	2.99	1.11 NS
Error	2677.79	995	2.69	

Appendix 26: Results of analyses of variance made on sensory data from non-vitaminized and vitaminized powders tested during the 1979/80 season for the sweet, creamy and cooked/caramelised notes in the flavour of the reconstituted milks.

SWEETNESS

Non-Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	33.60	4	8.40	3.08 *
Specification	39.40	4	9.85	3.61 **
Month	34.34	7	4.91	1.80 NS
Lack of Fit	41.50	29	1.43	0.52 NS
Error	1088.53	399	2.73	

Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	14.12	4	3.53	1.33 NS
Specification	45.15	11	4.10	1.55 NS
Month	43.04	8	5.38	2.03 *
Lack of Fit	121.49	43	2.83	1.07 NS
Error	1576.51	596	2.65	

CREAMINESS

Non-Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	29.38	4	7.35	3.94 **
Specification	27.69	4	6.92	3.71 **
Month	36.81	7	5.26	2.82 **
Lack of Fit	49.34	29	1.70	0.91 NS
Error	744.03	399	1.87	

Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	14.95	4	3.74	1.82 NS
Specification	39.09	11	3.55	1.73 NS
Month	54.29	8	6.79	3.29 **
Lack of Fit	57.06	43	1.33	0.64 NS
Error	1227.77	596	2.06	

Appendix 26 (continued)

COOKED/CARAMELISED

Non-Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	22.53	4	5.63	1.85 NS
Specification	12.67	4	3.17	1.04 NS
Month	79.25	7	11.32	3.71 ***
Lack of Fit	83.92	29	2.89	0.95 NS
Error	1216.54	399	3.05	

Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	15.46	4	3.87	1.58 NS
Specification	88.11	11	8.01	3.27 ***
Month	73.27	8	9.16	3.74 ***
Lack of Fit	138.67	43	3.22	1.32 NS
Error	1461.24	596	2.45	

Appendix 27: Results of analyses of variance made on sensory data from the 1980/81 season for the sweet, creamy and cooked/caramelised notes in the flavour of the reconstituted milks

SOURCE	SS	DF	MS	F
SWEETNESS				
Factory	24.37	4	6.09	4.01 **
Specification	212.19	14	15.16	9.97 ***
Month	106.41	8	13.30	8.75 ***
Lack of Fit	404.68	251	1.61	1.06 NS
Error	3782.40	2489	1.52	
CREAMINESS				
Factory	34.72	4	8.68	4.82 ***
Specification	158.76	14	11.34	6.30 ***
Month	205.09	8	25.64	14.24 ***
Lack of Fit	361.09	251	1.44	0.80 NS
Error	4481.32	2489	1.80	
COOKED/CARAMELISED				
Factory	10.24	4	2.56	1.37 NS
Specification	126.37	14	9.03	4.83 ***
Month	9.33	8	1.17	0.62 NS
Lack of Fit	425.14	251	1.69	0.91 NS
Error	4650.95	2489	1.87	

Appendix 28: Results of analyses of variance made on early and late season sensory data from the 1980/81 season for the sweet and creamy notes in the flavour of the reconstituted milks.

SWEETNESS

Early Season Data

SOURCE	SS	DF	MS	F
Factory	13.79	4	3.45	2.31 NS
Specification	187.60	11	17.05	11.42 ***
Fortnight	12.55	4	3.14	2.10 NS
Lack of Fit	152.35	102	1.49	1.00 NS
Error	1634.23	1094	1.49	

Late Season Data

SOURCE	SS	DF	MS	F
Factory	15.84	4	3.96	2.74 *
Specification	28.21	13	2.17	1.50 NS
Fortnight	21.01	4	5.25	3.64 **
Lack of Fit	140.77	100	1.41	0.98 NS
Error	1577.33	1093	1.44	

CREAMINESS

Early Season Data

SOURCE	SS	DF	MS	F
Factory	7.61	4	1.90	1.16 NS
Specification	130.18	11	11.83	7.22 ***
Fortnight	5.21	4	1.30	0.80 NS
Lack of Fit	159.72	102	1.57	0.96 NS
Error	1792.76	1094	1.64	

Late Season Data

SOURCE	SS	DF	MS	F
Factory	29.93	4	7.48	3.88 **
Specification	30.52	13	2.35	1.22 NS
Fortnight	8.88	4	2.22	1.15 NS
Lack of Fit	111.30	100	1.11	0.58 NS
Error	2108.11	1093	1.93	

Appendix 29: Results of analyses of variance on sensory data from the 1979/80 season for the lactone-like, oxidised, feedy, taint and age-related notes in the flavour of the reconstituted milks.

LACTONE-LIKE

SOURCE	SS	DF	MS	F
Factory	145.70	4	36.42	0.61 NS
Specification	4359.79	18	242.21	4.07 ***
Month	473.94	8	59.24	0.99 NS
Error	4820.93	81	59.52	

OXIDISED

SOURCE	SS	DF	MS	F
Factory	69.34	4	17.33	0.91 NS
Specification	1082.90	18	60.16	3.17 ***
Month	226.11	8	28.26	1.49 NS
Error	1536.98	81	18.98	

FEEDY

SOURCE	SS	DF	MS	F
Factory	44.33	4	11.08	2.74 *
Specification	622.00	18	34.56	8.54 ***
Month	20.22	8	2.53	0.62 NS
Error	327.81	81	4.05	

TAINT

SOURCE	SS	DF	MS	F
Factory	84.66	4	21.16	2.03 NS
Specification	475.53	18	26.42	2.53 **
Month	302.33	8	37.79	3.62 **
Error	846.23	81	10.45	

AGE-RELATED

SOURCE	SS	DF	MS	F
Factory	7.63	4	1.91	0.50 NS
Specification	38.68	18	2.15	0.56 NS
Month	53.18	8	6.65	1.74 NS
Error	309.05	81	3.82	

Appendix 30: Results of analyses of variance made on sensory data from the non-vitaminized and vitaminized powders tested during the 1979/80 season for the taint note in the flavour of the reconstituted milks.

Non-Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	16.15	4	4.04	0.42 NS
Specification	59.09	4	14.78	1.52 NS
Month	294.59	7	42.08	4.33 **
Error	281.97	29	9.72	

Vitaminized Powders

SOURCE	SS	DF	MS	F
Factory	199.38	4	49.84	6.42 ***
Specification	515.22	11	46.84	6.03 ***
Month	192.82	8	24.10	3.10 **
Error	333.99	43	7.77	

Appendix 31: Results of analyses of variance made on sensory data from the 1980/81 season for the lactone-like, oxidised, feedy, vitaminized, taint and age-related notes in the flavour of the reconstituted milks.

LACTONE-LIKE

SOURCE	SS	DF	MS	F
Factory	10.93	4	2.73	0.90 NS
Specification	141.45	14	10.10	3.34 ***
Month	39.29	8	4.91	1.62 NS
Lack of Fit	882.25	251	3.51	1.16 NS
Error	725.49	2489	3.02	

OXIDISED

SOURCE	SS	DF	MS	F
Factory	4.50	4	1.13	0.55 NS
Specification	681.73	14	48.69	23.83 ***
Month	71.15	8	8.89	4.35 ***
Lack of Fit	721.41	251	2.87	1.41 NS
Error	5086.28	2489	2.04	

FEEDY

SOURCE	SS	DF	MS	F
Factory	4.10	4	1.02	1.33 NS
Specification	15.55	14	1.11	1.44 NS
Month	15.68	8	1.96	2.53 **
Lack of Fit	211.79	251	0.84	1.09 NS
Error	1924.09	2489	0.77	

Appendix 31 (continued)

VITAMINIZED

SOURCE	SS	DF	MS	F
Factory	37.16	4	9.29	2.29 NS
Specification	643.59	14	45.79	11.34 ***
Month	106.45	8	13.31	3.28 **
Lack of Fit	905.62	251	3.61	0.89 NS
Error	10094.30	2489	4.06	
TAINT				
Factory	13.58	4	3.39	3.67 **
Specification	22.66	14	1.62	1.75 *
Month	8.97	8	1.12	1.21 NS
Lack of Fit	221.16	251	0.88	0.95 NS
Error	2302.48	2489	0.93	
AGE-RELATED				
Factory	3.42	4	0.85	2.65 *
Specification	7.84	14	0.56	1.74 *
Month	6.40	8	0.80	2.48 *
Lack of Fit	73.91	251	0.29	0.91 NS
Error	802.10	2489	0.32	

Appendix 32: Results of analyses of variance made on early and late season sensory data from the 1980/81 season for the oxidised, feedy, vitaminized and age-related notes in the flavour of the reconstituted milks.

OXIDISED

Early Season Data

SOURCE	SS	DF	MS	F
Factory	1.26	4	0.31	0.20 NS
Specification	442.56	11	40.23	24.89 ***
Fortnight	33.96	4	8.49	5.25 ***
Lack of Fit	219.96	102	2.16	1.33 *
Error	1768.60	1094	1.62	

Late Season Data

SOURCE	SS	DF	MS	F
Factory	3.31	4	0.83	0.36 NS
Specification	256.97	13	19.77	8.64 ***
Fortnight	30.20	4	7.55	3.30 *
Lack of Fit	244.70	100	2.25	0.98 NS
Error	2499.93	1093	2.29	

FEEDY

Early Season Data

SOURCE	SS	DF	MS	F
Factory	13.92	4	3.48	3.38 **
Specification	29.27	11	2.66	2.59 **
Fortnight	12.08	4	3.02	2.94 *
Lack of Fit	110.75	102	1.09	1.06 NS
Error	1124.56	1094	1.03	

Late Season Data

SOURCE	SS	DF	MS	F
Factory	3.18	4	0.80	1.30 NS
Specification	7.81	13	0.60	0.98 NS
Fortnight	5.25	4	1.31	2.14 NS
Lack of Fit	51.42	100	0.51	0.84 NS
Error	670.27	1093	0.61	

Appendix 32 (continued)

VITAMINIZED

Early Season Data

SOURCE	SS	DF	MS	F
Factory	30.18	4	7.54	1.56 NS
Specification	212.13	11	19.28	3.99 ***
Fortnight	15.90	4	3.98	0.82 NS
Lack of Fit	377.97	102	3.71	0.77 NS
Error	5279.69	1094	4.83	
Late Season Data				
Factory	7.37	4	1.84	0.58 NS
Specification	289.19	13	22.24	7.02 ***
Fortnight	31.20	4	7.80	2.46 *
Lack of Fit	275.80	100	2.76	0.87 NS
Error	3461.68	1093	3.17	
AGE-RELATED				
Early Season Data				
Factory	0.13	4	0.03	0.25 NS
Specification	3.36	11	0.31	2.28 **
Fortnight	0.60	4	0.15	1.12 NS
Lack of Fit	13.87	102	0.14	1.02 NS
Error	146.20	1094	0.13	
Late Season Data				
Factory	3.23	4	0.81	1.62 NS
Specification	8.96	13	0.69	1.38 NS
Fortnight	2.17	4	0.54	1.09 NS
Lack of Fit	31.90	100	0.32	0.64 NS
Error	545.20	1093	0.50	

Appendix 33: Results of analyses of variance made on sensory data from the experimental powders containing controlled levels of vitamins and iron for the sweet, buttery and cooked/caramelised notes in the aroma of the powders.

SWEETNESS

SOURCE	SS	DF	MS	F
Vitamin	2.13	1	2.13	1.61 NS
Iron	6.08	1	6.08	4.59 *
Vitamin x Iron	0.03	1	0.03	0.03 NS
Position	0.83	1	0.83	0.63 NS
Vitamin x Position	0.21	1	0.21	0.16 NS
Iron x Position	0.03	1	0.03	0.03 NS
Type	9.18	2	4.59	3.47 *
Vitamin x Type	0.88	2	0.44	0.33 NS
Iron x Type	1.66	2	0.83	0.68 NS
Position x Type	0.70	2	0.35	0.27 NS
Error 1	26.42	32	0.83	0.62 NS
Subsamples	571.80	432	1.32	

BUTTERINESS

SOURCE	SS	DF	MS	F
Vitamin	1.88	1	1.88	1.06 NS
Iron	7.01	1	7.01	3.96 *
Vitamin x Iron	0.08	1	0.08	0.04 NS
Position	11.41	1	11.41	6.45 *
Vitamin x Position	0.41	1	0.41	0.23 NS
Iron x Position	0.21	1	0.21	0.12 NS
Type	16.22	2	8.11	4.58 *
Vitamin x Type	6.45	2	3.23	1.82 NS
Iron x Type	4.07	2	2.03	1.15 NS
Position x Type	4.52	2	2.26	1.28 NS
Error 1	53.75	32	1.68	0.95 NS
Subsamples	764.60	432	1.77	

COOKED/CARAMELISED

SOURCE	SS	DF	MS	F
Vitamin	1.20	1	1.20	0.71 NS
Iron	1.20	1	1.20	0.71 NS
Vitamin x Iron	1.01	1	1.01	0.60 NS
Position	0.01	1	0.01	0.01 NS
Vitamin x Position	0.30	1	0.30	0.18 NS
Iron x Position	0.03	1	0.03	0.02 NS
Type	4.32	2	2.16	1.28 NS
Vitamin x Type	0.00	2	0.00	0.00 NS
Iron x Type	1.95	2	0.98	0.58 NS
Position x Type	2.12	2	1.06	0.63 NS
Error 1	43.33	32	1.35	0.81 NS
Subsamples	726.00	432	1.68	

Appendix 34: Results of analyses of variance made on sensory data from the experimental powders containing controlled levels of vitamins and iron for the lactone-like, oxidised, feedy, vitaminized, taint and age-related notes in the aroma of the powders.

LACTONE-LIKE

SOURCE	SS	DF	MS	F
Vitamin	0.13	1	0.13	0.07 NS
Iron	0.41	1	0.41	0.23 NS
Vitamin x Iron	1.63	1	1.63	0.90 NS
Position	1.20	1	1.20	0.66 NS
Vitamin x Position	2.41	1	2.41	1.33 NS
Iron x Position	2.70	1	2.70	1.49 NS
Type	0.84	2	0.42	0.23 NS
Vitamin x Type	3.78	2	1.89	1.04 NS
Iron x Type	4.83	2	2.41	1.33 NS
Position x Type	5.34	2	2.67	1.47 NS
Error 1	64.65	32	2.02	1.12 NS
Subsamples	781.40	432	1.81	

OXIDISED

SOURCE	SS	DF	MS	F
Vitamin	0.03	1	0.03	0.03 NS
Iron	0.01	1	0.01	0.01 NS
Vitamin x Iron	0.53	1	0.53	0.51 NS
Position	0.30	1	0.30	0.29 NS
Vitamin x Position	0.08	1	0.08	0.07 NS
Iron x Position	0.13	1	0.13	0.13 NS
Type	9.48	2	4.74	4.54 *
Vitamin x Type	1.08	2	0.54	0.52 NS
Iron x Type	0.53	2	0.26	0.25 NS
Position x Type	0.26	2	0.13	0.13 NS
Error 1	31.88	32	0.99	0.95 NS
Subsamples	450.80	432	1.04	

FEEDY

SOURCE	SS	DF	MS	F
Vitamin	0.17	1	0.17	0.21 NS
Iron	0.05	1	0.05	0.06 NS
Vitamin x Iron	0.60	1	0.60	0.74 NS
Position	0.05	1	0.05	0.06 NS
Vitamin x Position	0.17	1	0.17	0.21 NS
Iron x Position	1.75	1	1.75	2.16 NS
Type	1.02	2	0.51	0.63 NS
Vitamin x Type	0.95	2	0.48	0.59 NS
Iron x Type	3.52	2	1.76	2.17 NS
Position x Type	0.02	2	0.01	0.01 NS
Error 1	35.48	32	1.11	1.37 NS
Subsamples	349.90	432	0.81	

Appendix 34 (continued)

VITAMINIZED

SOURCE	SS	DF	MS	F
Vitamin	1.52	1	1.52	0.70 NS
Iron	0.17	1	0.17	0.08 NS
Vitamin x Iron	0.60	1	0.60	0.28 NS
Position	1.52	1	1.52	0.70 NS
Vitamin x Position	0.25	1	0.25	0.12 NS
Iron x Position	0.02	1	0.02	0.01 NS
Type	0.03	2	0.02	0.01 NS
Vitamin x Type	1.21	2	0.61	0.28 NS
Iron x Type	1.66	2	0.83	0.39 NS
Position x Type	0.46	2	0.23	0.10 NS
Error 1	53.03	32	1.66	0.77 NS
Subsamples	931.70	432	2.16	

TAINT

SOURCE	SS	DF	MS	F
Vitamin	2.55	1	2.55	5.59 *
Iron	1.30	1	1.30	2.85 NS
Vitamin x Iron	0.60	1	0.60	1.32 NS
Position	0.25	1	0.25	0.55 NS
Vitamin x Position	1.10	1	1.10	2.41 NS
Iron x Position	0.35	1	0.35	0.77 NS
Type	0.52	2	0.26	0.57 NS
Vitamin x Type	0.82	2	0.41	0.89 NS
Iron x Type	0.07	2	0.03	0.07 NS
Position x Type	0.07	2	0.03	0.07 NS
Error 1	12.55	32	0.39	0.86 NS
Subsamples	197.30	432	0.46	

AGE-RELATED

SOURCE	SS	DF	MS	F
Vitamin	0.30	1	0.30	1.73 NS
Iron	0.03	1	0.03	0.19 NS
Vitamin x Iron	0.21	1	0.21	1.20 NS
Position	0.13	1	0.13	0.77 NS
Vitamin x Position	0.08	1	0.08	0.43 NS
Iron x Position	0.08	1	0.08	0.43 NS
Type	0.00	2	0.00	0.00 NS
Vitamin x Type	0.09	2	0.04	0.25 NS
Iron x Type	0.03	2	0.01	0.08 NS
Position x Type	0.20	2	0.10	0.59 NS
Error 1	5.41	32	0.17	0.97 NS
Subsamples	75.00	432	0.17	

Appendix 35: Results of analyses of variance made on sensory data from the experimental powders containing controlled levels of vitamins and iron for the sweet, buttery and cooked/caramelised notes in the aroma of the reconstituted milks.

SWEETNESS

SOURCE	SS	DF	MS	F
Vitamin	1.10	1	1.10	0.60 NS
Iron	31.52	1	31.52	17.03 ***
Vitamin x Iron	2.85	1	2.85	1.54 NS
Position	1.75	1	1.75	0.95 NS
Vitamin x Position	0.17	1	0.17	0.09 NS
Iron x Position	0.75	1	0.75	0.41 NS
Type	96.02	2	48.01	25.95 ***
Vitamin x Type	6.72	2	3.36	1.82 NS
Iron x Type	29.45	2	14.73	7.96 ***
Position x Type	1.52	2	0.76	0.41 NS
Error 1	44.98	32	1.41	0.76 NS
Subsamples	799.10	432	1.85	

BUTTERINESS

SOURCE	SS	DF	MS	F
Vitamin	0.10	1	0.10	0.07 NS
Iron	18.80	1	18.80	13.29 ***
Vitamin x Iron	0.02	1	0.02	0.01 NS
Position	0.02	1	0.02	0.13 NS
Vitamin x Position	1.10	1	1.10	0.77 NS
Iron x Position	0.17	1	0.17	0.12 NS
Type	58.82	2	29.41	20.79 ***
Vitamin x Type	0.12	2	0.06	0.04 NS
Iron x Type	16.47	2	8.23	5.82 NS
Position x Type	1.20	2	0.70	0.49 NS
Error 1	25.03	32	0.78	0.55 NS
Subsamples	611.10	432	1.41	

COOKED/CARAMELISED

SOURCE	SS	DF	MS	F
Vitamin	1.75	1	1.75	1.05 NS
Iron	3.50	1	3.50	2.10 NS
Vitamin x Iron	0.92	1	0.92	0.55 NS
Position	0.75	1	0.75	0.45 NS
Vitamin x Position	0.47	1	0.47	0.28 NS
Iron x Position	0.75	1	0.75	0.45 NS
Type	45.07	2	22.53	13.54 ***
Vitamin x Type	0.22	2	0.11	0.06 NS
Iron x Type	22.87	2	11.43	6.87 **
Position x Type	10.47	2	5.23	3.14 *
Error 1	52.83	32	1.65	0.99 NS
Subsamples	719.10	432	1.66	

Appendix 36: Results of analyses of variance made on sensory data from the experimental powders containing controlled levels of vitamins and iron for the lactone-like, oxidised, feedy, vitaminized, taint and age-related notes in the aroma of the reconstituted milks.

LACTONE-LIKE

SOURCE	SS	DF	MS	F
Vitamin	6.08	1	6.08	3.62 NS
Iron	9.08	1	9.08	5.41 *
Vitamin x Iron	0.21	1	0.21	0.12 NS
Position	1.20	1	1.20	0.72 NS
Vitamin x Position	0.03	1	0.03	0.02 NS
Iron x Position	8.53	1	8.53	5.09 *
Type	13.63	2	6.81	4.06 *
Vitamin x Type	4.51	2	2.25	1.34 NS
Iron x Type	1.21	2	0.61	0.36 NS
Position x Type	1.36	2	0.68	0.41 NS
Error 1	34.74	32	1.09	0.65 NS
Subsamples	724.80	432	1.68	

OXIDISED

SOURCE	SS	DF	MS	F
Vitamin	7.25	1	7.25	1.56 NS
Iron	125.05	1	125.05	26.87 ***
Vitamin x Iron	0.75	1	0.75	0.16 NS
Position	16.50	1	16.50	3.55 NS
Vitamin x Position	1.10	1	1.10	0.24 NS
Iron x Position	2.27	1	2.27	0.49 NS
Type	417.87	2	208.93	44.89 ***
Vitamin x Type	3.02	2	1.51	0.32 NS
Iron x Type	149.07	2	74.53	16.02 ***
Position x Type	24.27	2	12.13	2.62 NS
Error 1	166.28	32	5.20	1.12 NS
Subsamples	2010.50	432	4.65	

FEEDY

SOURCE	SS	DF	MS	F
Vitamin	0.10	1	0.10	0.04 NS
Iron	0.17	1	0.17	0.07 NS
Vitamin x Iron	7.75	1	7.75	3.33 NS
Position	3.85	1	3.85	1.66 NS
Vitamin x Position	5.42	1	5.42	2.33 NS
Iron x Position	0.47	1	0.47	0.20 NS
Type	17.72	2	8.86	3.81 *
Vitamin x Type	0.82	2	0.41	0.18 NS
Iron x Type	3.80	2	1.90	0.82 NS
Position x Type	7.27	2	3.63	1.56 NS
Error 1	58.07	32	1.81	0.78 NS
Subsamples	1004.30	432	2.32	

Appendix 36 (continued)

VITAMINIZED

SOURCE	SS	DF	MS	F
Vitamin	200.21	1	200.21	31.95 ***
Iron	39.68	1	39.68	6.33 *
Vitamin x Iron	1.20	1	1.20	0.19 NS
Position	19.20	1	19.20	3.06 NS
Vitamin x Position	0.00	1	0.00	0.00 NS
Iron x Position	12.68	1	12.68	2.02 NS
Type	191.45	2	95.73	15.28 ***
Vitamin x Type	2.72	2	1.36	0.22 NS
Iron x Type	90.15	2	45.08	7.19 ***
Position x Type	54.20	2	27.10	4.32 *
Error 1	221.38	32	6.92	1.10 NS
Subsamples	2706.80	432	6.27	

TAINT

SOURCE	SS	DF	MS	F
Vitamin	1.30	1	1.30	2.89 NS
Iron	1.10	1	1.10	2.45 NS
Vitamin x Iron	0.25	1	0.25	0.56 NS
Position	0.35	1	0.35	0.78 NS
Vitamin x Position	0.02	1	0.02	0.04 NS
Iron x Position	1.52	1	1.52	3.38 NS
Type	0.25	2	0.13	0.28 NS
Vitamin x Type	0.63	2	0.31	0.70 NS
Iron x Type	2.08	2	1.04	2.31 NS
Position x Type	1.25	2	0.63	1.40 NS
Error 1	18.23	32	0.57	1.27 NS
Subsamples	194.10	432	0.45	

AGE-RELATED

SOURCE	SS	DF	MS	F
Vitamin	0.17	1	0.17	0.87 NS
Iron	0.00	1	0.00	0.00 NS
Vitamin x Iron	0.35	1	0.35	1.82 NS
Position	0.10	1	0.10	0.53 NS
Vitamin x Position	0.05	1	0.05	0.27 NS
Iron x Position	0.02	1	0.02	0.01 NS
Type	0.34	2	0.17	0.87 NS
Vitamin x Type	0.04	2	0.02	0.97 NS
Iron x Type	0.20	2	0.10	0.53 NS
Position x Type	0.40	2	0.20	1.04 NS
Error 1	5.78	32	0.18	0.93 NS
Subsamples	83.70	432	0.19	

Appendix 37: Results of analyses of variance made on sensory data from the experimental powders containing controlled levels of vitamins and iron for the sweet, creamy and cooked/caramelised notes in the flavour of the reconstituted milks.

SWEETNESS

SOURCE	SS	DF	MS	F
Vitamin	2.55	1	2.55	0.96 NS
Iron	36.85	1	36.85	13.89 ***
Vitamin x Iron	1.30	1	1.30	0.49 NS
Position	0.10	1	0.10	0.04 NS
Vitamin x Position	0.35	1	0.35	0.13 NS
Iron x Position	0.60	1	0.60	0.23 NS
Type	223.45	2	111.73	42.11 ***
Vitamin x Type	0.38	2	0.20	0.07 NS
Iron x Type	23.28	2	11.64	4.39 *
Position x Type	3.20	2	1.60	0.60 NS
Error 1	89.02	32	2.78	1.04 NS
Subsamples	1146.30	432	2.65	

CREAMINESS

SOURCE	SS	DF	MS	F
Vitamin	11.10	1	11.10	5.34 *
Iron	22.97	1	22.97	11.04 ***
Vitamin x Iron	2.85	1	2.85	1.37 NS
Position	0.10	1	0.10	0.05 NS
Vitamin x Position	0.35	1	0.35	0.17 NS
Iron x Position	2.27	1	2.27	1.09 NS
Type	71.40	2	35.70	17.16 ***
Vitamin x Type	2.28	2	1.14	0.55 NS
Iron x Type	17.59	2	8.79	4.23 *
Position x Type	1.93	2	0.96	0.46 NS
Error 1	47.18	32	1.47	0.71 NS
Subsamples	898.90	432	2.08	

COOKED/CARAMELISED

SOURCE	SS	DF	MS	F
Vitamin	8.27	1	8.27	3.96 *
Iron	0.75	1	0.75	0.36 NS
Vitamin x Iron	4.60	1	4.60	2.20 NS
Position	0.46	1	0.47	0.22 NS
Vitamin x Position	0.02	1	0.02	0.01 NS
Iron x Position	0.00	1	0.00	0.00 NS
Type	97.74	2	48.87	23.38 ***
Vitamin x Type	1.29	2	0.64	0.31 NS
Iron x Type	14.03	2	7.01	3.36 *
Position x Type	3.39	2	1.69	0.81 NS
Error 1	38.53	32	1.20	0.58 NS
Subsamples	902.90	432	2.09	

Appendix 38: Results of analyses of variance made on sensory data from the experimental powders containing controlled levels of vitamins and iron for the lactone-like, oxidised, feedy, vitaminized, taint and age-related notes in the flavour of the reconstituted milks.

LACTONE-LIKE

SOURCE	SS	DF	MS	F
Vitamin	39.68	1	39.68	12.89 ***
Iron	14.01	1	14.01	4.55 *
Vitamin x Iron	1.01	1	1.01	0.33 NS
Position	1.63	1	1.63	0.53 NS
Vitamin x Position	0.30	1	0.30	0.01 NS
Iron x Position	7.50	1	7.50	2.44 NS
Type	80.86	2	40.43	13.14 ***
Vitamin x Type	9.71	2	4.86	1.58 NS
Iron x Type	0.03	2	0.02	0.01 NS
Position x Type	8.18	2	4.09	1.33 NS
Error 1	58.01	32	1.81	0.59 NS
Subsamples	1329.20	432	3.08	

OXIDISED

SOURCE	SS	DF	MS	F
Vitamin	0.75	1	0.75	0.15 NS
Iron	119.00	1	119.00	24.41 ***
Vitamin x Iron	0.05	1	0.05	0.01 NS
Position	10.50	1	10.50	2.15 NS
Vitamin x Position	0.17	1	0.17	0.03 NS
Iron x Position	0.17	1	0.17	0.03 NS
Type	1035.46	2	517.73	106.19 ***
Vitamin x Type	4.28	2	2.14	0.44 NS
Iron x Type	46.09	2	23.04	4.73 **
Position x Type	40.33	2	20.17	4.14 *
Error 1	301.88	32	9.43	1.94 **
Subsamples	2106.10	432	4.88	

FEEDY

SOURCE	SS	DF	MS	F
Vitamin	0.08	1	0.08	0.07 NS
Iron	3.01	1	3.01	2.72 NS
Vitamin x Iron	0.01	1	0.01	0.01 NS
Position	1.63	1	1.63	1.47 NS
Vitmain x Position	0.03	1	0.03	0.03 NS
Iron x Position	1.63	1	1.63	1.47 NS
Type	1.05	2	0.53	0.47 NS
Vitamin x Type	0.65	2	0.33	0.29 NS
Iron x Type	2.22	2	1.11	1.00 NS
Position x Type	1.67	2	0.83	0.75 NS
Error 1	47.25	32	1.48	1.33 NS
Subsamples	478.40	432	1.12	

Appendix 38 (continued)

VITAMINIZED

SOURCE	SS	DF	MS	F
Vitamin	313.63	1	313.63	41.99 ***
Iron	20.83	1	20.83	2.78 NS
Vitamin x Iron	2.41	1	2.41	0.32 NS
Position	3.33	1	3.33	0.44 NS
Vitamin x Position	5.21	1	5.21	0.70 NS
Iron x Position	9.08	1	9.08	1.21 NS
Type	283.63	2	141.82	18.99 ***
Vitamin x Type	5.38	2	2.68	0.36 NS
Iron x Type	37.95	2	18.98	2.54 NS
Position x Type	48.30	2	24.15	3.23 *
Error 1	213.90	32	6.68	0.89 NS
Subsamples	3226.80	432	7.47	

TAINT

SOURCE	SS	DF	MS	F
Vitamin	0.00	1	0.00	0.00 NS
Iron	2.27	1	2.27	3.47 NS
Vitamin x Iron	0.25	1	0.25	0.38 NS
Position	0.47	1	0.47	0.72 NS
Vitamin x Position	1.52	1	1.52	2.32 NS
Iron x Position	0.60	1	0.60	0.92 NS
Type	0.61	2	0.31	0.47 NS
Vitamin x Type	1.30	2	0.65	0.99 NS
Iron x Type	0.76	2	0.38	0.58 NS
Position x Type	0.04	2	0.02	0.03 NS
Error 1	24.58	32	0.77	1.18 NS
Subsamples	282.30	432	0.65	

AGE-RELATED

SOURCE	SS	DF	MS	F
Vitamin	0.05	1	0.05	0.56 NS
Iron	0.02	1	0.02	0.20 NS
Vitamin x Iron	0.05	1	0.05	0.56 NS
Position	0.35	1	0.35	3.76 NS
Vitamin x Position	0.05	1	0.05	0.55 NS
Iron x Position	0.02	1	0.02	0.20 NS
Type	0.18	2	0.09	0.96 NS
Vitamin x Type	0.18	2	0.09	0.96 NS
Iron x Type	0.01	2	0.01	0.07 NS
Position x Type	0.18	2	0.09	0.96 NS
Error 1	3.00	32	0.09	1.00 NS
Subsamples	40.50	432	0.09	