Short Review : Statistics and Different Departments of Food Industry

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ABSTRACT: In food science research, the recording and analysing the date from food science experiments is complex. Statistical methods are applied to study food processing, sensory quality, quality control etc.in the industry. There exists misunderstanding that statistics is viewed as a difficult subject. In this review article, the applications of statistical procedure in food science research have been discussed. The discussion of statistical analysis application in food science will cover new food product development, food sensory analysis, food instrument analysis and food quality control. It indicates that statistics is a useful tool in the food science.

Keywords: statistics, food product development, food sensory analysis, food instrument analysis, food quality control

1. INTRODUCTION

Safe, nutritious and palatable products are important to the food industry. New food product developments are the most important part for most food company in the food business, which play the important role in competition and keeping market sharing. The modern-day scientist and other practitioners with a background of science are engaged in laboratory, production and research activities. Sometime, they also work in some areas such as marketing, consumer science. Those food scientists may encounter data interpretation and dissemination on a daily basis. There are plenty of data from the laboratory experiments and consumers survey from the user and receivers of the end products. It is necessary to understand the information which contains in those raw data. In this situation, statistical methods become the essential in food science. The basis of statistical methods will help to analyse the conclusion and decision aid. For example, scientists applied the analysis to determine amount of toxin in food or nutrient content in food. Statistical techniques play the key role in monitoring and reporting of chemical analysis. Statistical scrutiny with trustworthiness will provide food manufacturers the reassurance of product characteristics within the required limits for legal chemical content, microbiological and consumer acceptability. In food processing, Statistical quality control methods will be used to monitor online production of food and make sure manufacturing. New product development is the major activity in the food industry. The products are a bundle of benefits, relating its tangible and intangible attribute to consumer need. A company defines a new product as having some difference in the basic functions and aesthetic presentation. The successful achievement of the new product development success should be from financial success, product success, consumer success. For food scientist, the product development project is one of part of the success analysis its efficiency and effectiveness. Quantitative design specification, experiment instrument data measurement, consumer sensory analysis and food manufacture quality assurance will contribute to the successful new product development. Product design specifications state the consumer's product concept, the

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quantitative target for the product qualities, processing parameters and market needs. The integration of people with different skill and knowledge from the different department is required. Statistics is the tool to help scientists get information from the experiments results, consumers sensory test, manufactures parameter and quality assurance. Instrumental measures can cover any measurement system from chemical and physical to specific food instrumentation. In the sensory measures, the trained assessors apply descriptive analysis methods or discrimination tests to find the difference between treatments. In the consumer test, hedonic in nature, e.g. preference ranking are affective. All of them require powerful statistics tool to get the conclusion. The purpose of this review is to introduce some statistics application in food formula design, food sensory test, food instrument test and quality assurance. Statistics is a powerful tool to aid food scientist in food science research.

2. STATISTICS IN FOOD FORMULA DESIGN

2.1. Design application in food development

New product development is important for food companies. However, the failure rate of new product development is high. One of reason for the failure is less organized approach. New product process have many stages developing innovation strategy, understanding consumers, formulation development, instrument measurement, sensory test and food product processing [1]. Making the formulation is the first step. Efficient experiment design can save a lot time and achieve the best results. The essentials of formulation studies are identified as factors and are combined at various levels to produce a set of prototypes. The best one will be choose to allow continuing work. In the other word, the optimum levels of ingredients for sensory acceptability with minimum cost will be identified. In the proposed product, ingredients are factors with either quantities or types as the level-quantitative and qualitative ingredients. However, one way or two way factorial experiment bring the disadvantages of doing one factor in isolation to others. So the final formula had to test all factors together. In some case, if one key ingredient has play the key role in formulation and other factors has a little effect on formulation or no interaction with other ingredients. Moreover, with the number of factors and levels increasing, the size of experiments can become large. It is necessary to reduce the experimentation by certain design such as factional design.

2.2. One factor in the food formula design

One factor is called one variable experiment. The fixed level of ingredient is independent variable. The result is the dependent response. In some instrument measure, a linear relationship is built to achieve a certain level of viscosity in some sauce viscosity. Most food experiment data indicates linear relationship and effect. However, in some sensory tests, sensory sourness has a negative relationship with consumer hedonic rating over the range. A regression study with correlation and prediction via regression equation can use for the evaluation of ingredient level required for desired level of the response. The high fit of R^2 is used for prediction of the confidence within the limit of the experiments data. In food science experiment, the formulation has several formulations including several ingredients. One is variable factor and the others keep constant. Bear et al. [2] tried to find the different level of emulsifiers had impact to low fat ice cream by fixing the level of milk SNF, sucrose, corn syrup solids, maltodextrin and stabilizer. They found nonfat ice cream with 0.25% added monoglyceride and diglyceride achieve the highest overall score of ice cream. This types study can only refer to the formulation effect as a whole formulation effect rather than to specific ingredient effect.

2.3. Two factors or more factors in the food formula design.

When more than one ingredient in the design, a factorial experiment design is required. The factor can be a quantitative factor or a qualitative factor. The number of factors and level decides the size of the experiments in term of the number of treatments. The purpose of experiment design is to determine any ingredient has a significant effect on response measure. ANOVA is useful to determine the

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significant effect. The null hypothesis is requiring for the analysis. Wenpu Chen et al. [3] use one way ANOVA to determine the physical property of different treatment and find the desirable SSPS fortified products.

With increasing factors in the formulation, a major of drawback is the number of ingredients which will lead to increasing number of treatments. For example, 4 ingredients at 2 levels each will lead to 16 treatments. The number of treatments would be difficult for a sensory panel to assess in one time. Blocking techniques could be used to reduce the number of treatments. However, this treatment will relying on the linear response. When the experiment did not employ replication, the formulation design cannot be used to assess batch-to-batch variation. However, a factorial experiment hasmany advantages-simple and clear interpretations of results. In some case, screening experiment is used to help the number of treatment by identifying the factors (ingredients) which has major effect on the response. Screening experiment can contain all ingredients. A fractional structure experiment is used. The fractions can be achieved by removing treatment combinations with effects of less importance and lower effects. The technique of blocking in experiment design is used in one form as a device to reduce the number of experiment in one session. In 2005, Lee and Glimore [4] applied empirical screening model to build and optimize the planning experiments and reduce the size of experiments.

3. STATISTICS IN FOOD EXPERIMENT INSTRUMENT MEASUREMENT

In the food science, there are a lot of experiments and investigations to make sure legal compositional requirements and limit of constituents for legal and safety reasons. Instrument data is necessary for the food processing and research. Compared with the other measurement, instrument data has less error because of less human intervention to sampling. However, the stage of preparation will contribute the error of result. For example, mechanical testing machine can measure empirical and fundamental properties of food texture. the sample preparation will contribute the errors. The combined error results in uncertainty of the measurement. Improvement in accuracy will be offset by the additional work involved. Normally, a variety and graph types can be used to summary the instrument data. The standard deviation and standard error are commonly presented in table or graphs with average values of instrument data.

Correlation is the measure of the degree of association between two variables when both are measured on a series of objects. The strength of the correlation is given by the correlation coefficient. The coefficients provide information about the relationship. If they change in the same direction, the correlation coefficient is high and positive. A change in the opposite direction for one versus the other can also result in a high negative nature. The correlation analysis can establish that a relationship exists. Whether or not this relationship of linear and the test is significantly. The information can be used to devise following experiments and gain more understanding to postulate hypotheses. For example, a high correlation between the level of consumption of food ingredients and a health status index may or may not the constituent is affecting health. Further experiment need to conduct to ascertain such effect with more confidence. Method of calculation for both these measures are mentioned fully [5]. A scatter diagram is used to display the relationship between two variables. The scatter diagram will indicate the obvious relationship and the validity of the procedure can be revealed. Sample curve reflects the sampling variation. Macfie and Herdderley[6] indentified non-linear relationship technique analysis reveal the main flaws in the correlation analysis of hedonic response with instrumental measures. The correlation analysis can establish that a relationship which it may be from linear or not. The test will be significant. The latter procedure can be done by simply reading value from scatter diagram. The objective of correlation analysis is to ascertain whether or not there are a relationship between two variables and whether the relationship is statistically significantly.

Another statistics tool used in experiments instrument measurement is regression analysis.

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One variable (x) was design as the independent. And the other (y) is designated as the dependent. The regression equation allows prediction of values of dependent from independent value. The well-known regression equation is Y=bx+a , which is the common linear. The assumption of a linear relationship is explicit in this case. An exploratory stage and both the variables are random; either can be used to predict the other. Significance testing of the regression is hypothesized in term of whether the slope is sufficiently different from zero. Two methods appear in statistical texts: t-test [5] or an ANOVA style calculation is performed. The significance of level of a correlation or regression coefficient is standard significantly.

Towker and Shepherd [7] applied the correlation and regression to study attitude and beliefs in the relationship of a high fat food. Many analytical methods need to conduct the Calibration because the usual assumptions of linearity and there are no errors produced when the standards are made up and analyzed. The error in both and intercept need to be calculated. High coefficients would be expected (r>0.9).

4. STATISTICS IN FOOD SENSORY TEST

Sensory evaluation comprises a set of techniques for accurate measurement of human response to food and minimizes the potentially bias effects given by brand identity and others. Sensory test gives the important information on consumer perception. The major function of sensory analysis is to provide reliable sensory measurement. Statistical inference is the theoretical basis of sensory test. There are two kind of sensory tests-laboratory sensory and consumer analysis. In the laboratory analysis, a trained panel is used as analytical instrument to measure the sensory properties of the products. In the consumer sensory analysis, a sample of specified consumer population is used to test and predict consumer response for products. Although, the two type of sensory analysis have different goal and functions, they have same methodologies. Discriminative and descriptive analysis are the main classes of methodology. Discrimination is applied to determine whether a difference exists between treatments for confusable sensory properties of products by using ranking scale. The descriptive analysis is to characterize a product' sensory attributes or to rate a specific characteristic difference exists among products. Acceptance testing is also called quantitative descriptive analysis. In standard discrimination method, six common discrimination methods are applied-the 2-Alternative forced choice method, 3-alternative forced choice method, the Duo-Trio method, the triangular method, the A-not A method and the same-different method [8]. Discrimination testing is involved in a binominal experiment. Statistical table derived from the binomial distribution give the minimum number of correct responses needed to conclude statistical significance. It includes different testing and preference testing. A binomial experiment has the properties- n trials in the experiments, two response, independent trial and constant probability. The precision, accuracy, sensitivity and avoiding false positive results are concerned [9]. A discrimination test is based on the statistics of frequency and proportion. Simple difference test will be conducted with 25-40 participants who have been screened for their sensory acuity to common products. Those participants are familiar with test procedure. The big sample size is needed to clear sensory difference. Statistical tables derived from the binominal distribution give the minimum number of correct response need to conclude statistical significant difference. Discrimination tests have proven very useful in the application to indicate the difference of two samples. Jimrnez et al. [10] used paired comparison test to detect threshold of conjugated linoleic acid in dairy products.

The data from discrimination test may be analyzed by any of the following statistical methods. The binomial, Chi-square or normal distributions are used to assess the data. The binomial distributions allow the sensory specialist to determine whether the result of the study was due to chance alone or whether the panellists actually perceived a difference between the samples. The follow formulas allowthe scientists to calculate the probability of failure or success.

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$P(y)= \{n! / y! (n-y)!\} p^y . p^{n-y}$

n is the total number of judgment, y is the total number of correct judgment, p= probability of making the correct judgment by chance.

Some tables published are used to calculate the number of correct judgments and probability of occurrence [11]. The Chi-square distribution allows the sensory scientist to compare a set of observed frequencies with a matching set of expected frequencies. The Chi-square statistic can be calculated from the following formula

$X^2=[(\backslash O_2-E_2\backslash-0.5)^2/E_1]+[\backslash O_2-E_2\backslash-0.5)^2/E_2]$.

$Q_1$is the observation number of correct choice. Q2is observed number in corrected choice. E1 is expected number of correct choices. P and q value depends on the types of tests.

Z-test is also used to estimate the probability of chance in results of discrimination tests. According to Stone and Sidel [12], the follow equations are used to calculate the z-value associated with the results of a specific discrimination test.

$Z=\{[P_{obs}-P_{chance}] -1/2N\}/(pq/n)^{-1/2}$,

$P_{OBS}=X/N$, Pchance = properties of correct decision by chance, X=number of correct judgment, N=total number of judgment. In the Z-test, a Z-table will be used to determine the probability of this choice being made by chance.

In all sensory test, there are two types of errors which be made when testing null hypothesis (H_O). The types I occurs when the null hypothesis is rejected when it is actually true. When making a type I error in a discrimination test we would draw the conclusion that two products are actually not perceptible different however they are perceived to be different. The food scientist use the choice of size of alpha to control the Type I error. A Type II error occurs when the sensory scientist accepts the null hypothesis (Ho) when it is actually false. The power of the test is depend on the magnitude of the difference between the samples, the size of alpha and the number of judges performing the test.

Descriptive sensory analyses are the most complex tools in the arsenal of the sensory scientist. The data from descriptive sensory analysis is used to obtain complete sensory descriptions of products, process variables, some sensory attribute to be accepted. A quantitative scale for intensity is applied to allow the data can be analyzed. There are several different descriptive analysis methods. Quantitative Descriptive Analysis (QDA) was developed since 1970s which were used for correction of flavor profile analysis [12]. Normally, training the panellist is the first step. Determining panellist reproducibility during training. The third step is evaluating samples. Sensory data sets can be large as trained panel size can number 10-12 individuals. Each sample has the number of measures for each attribute plus any replications. All data are assumed from interval scales which conform to normal and variances are similar. The resulting data can be analyzed statistically using analysis of variance and multivariate statistical techniques.

4.1. Similarity test in sensory test

Similarity testing is an important methodology in sensory and consumer research. In many case, the research purpose is not to find the difference but to demonstrate similarity between treatments for example, the manufacturer does not want consumers to notice the change in an ingredient and ideally conduct a test that concludes "no difference " . In the similarity testing, the null hypothesis testing of "no difference” which is used in different test is not appropriate for similarity test. In the similar test, the difference is viewed as the degree above chance probability. Lawless and Heyman[13] indicated that a large difference is defined by 50% detection above the chance probability and small difference is 25% above the chance probability. Ideally, the manufacturer hope there is 0% of proportion of assessors who can detect the difference. However, 20% is more used. Publish tables is used to indicate the maximum number of correct responses [14].

5.0. STATISTICS IN QUALITY CONTROL

The purpose of food processing is to produce safe, legal, nutritious and tasty foods. To achieve

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the goal, many manufacturer employ statistical quality assurance programmers. Quality control procedure includes sampling the materials, semi-final product and finished product from time to time. Statistical techniques provide a means to monitor level of quality at one or more critical points in the procedure. Statistical process control (SPC) is applied to monitor the several aspect of the products make -up and weight. In the real situation, the variations in food product need to be considered. The food manufacturer do not allow the below standard product to pass through quality control system. Normally, there are two types of statistical applications in quality control. One is to monitor trends in variable quality measures over time. Control charts is common tool to use. This measure is obtained from a sample drawn from the procedure line at periods according to a sampling plan. The other one is acceptance sampling procedure. They monitor the quality of incoming raw materials and the number of defective articles in consignments of goods. Acceptance sampling procedure are of major consequence because they decide actions in distinctly positive or negative manner, as "accept " or "not accept" .

In food industry, rapid measures of assessment are used for control within production. "live" control is a good practice. Data from quality control can be plotted to provide a graphical display of ongoing variability as records of compliance /non-compliance. Variable is used for data which are usually ratio level of measurement and continuous, and attribute is applied to nominal data measurement such as "accept" "not accept". Variable control charts monitor measures -net weight .volume and so on. Attribute control charts will record the defective items. Acceptance sampling can deal with occurrence of defects or faults in materials supplies. Sampling is the first step in this procedure. A full appreciation of the nature and function of sample selection procession is required. A random nature is necessary for quality control sampling. Sampling size, sampling frequency and sampling location are key issues. The end determination measure tasks. In the food factory, the population in the circumstance is infinite and samples are small and frequent in the control chart situation. In some factory with HACCP schemes, the critical control points are ideal points to gathering samples.

Control Chart is a standard technique for the food manufacturer to ensure the quality. The control chart requires ongoing output of data and sample are drawn at intervals. The upper control limit, nominal value and lower control limit are set in Control Chart in variables such as volume, physical dimension, color and chemical content. The nominal value in the x-bar is the mean. The is demarcated by a normal distribution spread. The limit line positions are based on the population distribution. Deviation from the population can indicate source of unusual variation. This variation is from machine sources or slight variation in food materials. The control charts is bases on the mean value plus three standard deviation. Control chart can be operated to decide possible out of control occurrences [15].

6. CONCLUSION

Food industry are involved in many parts -food new product development, experiments, measurement in food laboratory , sensory test to find the difference or similarity and quality assurance in the food processing. All of those steps are related to data collect and analysis- data interpretation and dissemination task on a dairy base. In this article, the statistical tools which was applied in the food new products development, instrument data management, sensory measurement and quality control. The knowledge of statistical methods will aid making of conclusion and increasing efficiency.

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