A THEORETICAL MODEL TO DESCRIBE FOOD QUALITY

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ABSTRACT

The overall evaluation of foodstuffs and its result: the numerical description of food quality, play an increasingly important role in scientific food research, in product development and in the field of quality control in food manufacture. In view of the commonly adopted determination of food quality, the computation of the overall quality index is based on the transformation of parameters of the chosen product attributes into dimensionless values between 0 and 1 (normalization) and on their weighted summation. The total value of the weighting factors amount to 1 in every case with 0 representing the worst and 1 the best food quality. Within the framework of the adaptation a continued development of the overall quality index, different statistical methods and the pattern recognition can be readily used.

INTRODUCTION

In evaluation of food quality, its complexity, dynamic variation and relativity raise a number of problems, for the solution and related decisions of which the application of the tools of systems analysis is indispensable. Quality is a concept that is based on a number of product attributes that basically determine their level of suitability to a concrete and predetermined use.

In order to formulate an evaluation pattern, the concept of food quality is outlined as follows (Molnar *et al.* 1979): The quality of food products, in conformity with consumer requirements, is determined by sensory attributes, chemical composition, physical properties, level of microbiological and toxicological contaminants, the shelf-life as well as packaging and labeling. Another unique trait of food quality is the hierarchical and dynamic interrelation of almost all of its attributes. For this reason, in formulating an evaluation system for food products, the investigation of interrelated effects should not be disregarded.

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From the outlined quality definitions it also follows that quality is a convention and it may therefore be considered as constant over a shorter period only, which, beyond the absolute level of product characteristics, is also dependent on the base values designated in specifications or norms. The variation of product characteristics determine the change in quality only if the specified base values and the condition of their determination (including methods of measurement) are unaltered. Evaluation is in fact a comparison with an ''étalon'', which means the location of the parameters of product attributed along a multivariate ''standard'' scale or space.

For the numerical description of food quality, evaluation methods with so-called quality indices have been introduced by Molnár (1984). These indices provide a framework for development of methods necessary for overall food evaluation necessary in both quality control and product development. In recent years food research has revealed new knowledge on the interdependency of chemical and physical properties whose synthesis and rational presentation is needed. In addition, high performance computers available for processing the existing or issuing data has provided means of calculation not previously practical.

The calculation of the overall quality index is based on the normalization by a predetermined method, of the attribute-parameters obtained by measurement or scoring and the transformed values are then weighting summarized.

MODEL DEVELOPMENT

Selection and Grouping of Attributes

Taking the definition of food quality as a starting point, generally the following groups of attributes are considered in evaluation: sensory attributes, chemical composition and physical properties, microbiological and toxicological contaminants, shelf-life, and packaging and labeling. Within a group of properties, the type of the product determines the attributes to be selected for consideration, based primarily on prior consultation with specialists. This technical judgement is of importance even if mathematical methods are used to select attributes. It is advisable to link the mathematical methods used in selecting attributes (e.g., principal component analysis) to the determination of the weighting factors for the selected attributes.

Possibilities of Parameter Normalization

In accordance with the evaluation method, the range of parameters involved in the evaluation should in any case be divided between 0 and 1. It is recommended to choose the limit values so as to have a ''sudden jump'' in product quality at these values. The parameter ascribed to zero indicates a food product greatly differing from specification. The maximum value of the product parameter is ascribed to 1. The theoretical normalization model of measured parameters is as follows:

Parameter scale		Scale of normalized parameters	
$/P_i \longrightarrow x_i/$			$/z_i/$
P_{opt}	x_{opt}	best parameter	1.00
P_{min}	x_{worst}	parameter under limit acceptance	0.00

Relationship between the normalized and the original values: $z_i = f\ /x_i/$ which may be linear or nonlinear.

For the evaluation methods formulated to date, the linearity of the relation was assumed, that is: the variation over the normalized value scale were assumed to be proportional to changes in quality. The linear relation is expressed in the continuous and in the sectionalized scale. In case of a continuous scale, linear transformation may be undertaken in accordance with the following mathematical equations:

a/ $z_i = \dfrac{x_i - x_{min}}{x_{max} - x_{min}}$ if $x_{max} > x_i > x_{min}$ and $x_{max} = x_{opt}$

b/ $z_i = \dfrac{x_{max} - x_i}{x_{max} - x_{min}}$ if $x_{max} > x_i > x_{min}$ and $x_{min} = x_{opt}$

c_1/ $z_i = \dfrac{x_{max} - x_i}{x_{max} - x_B}$ if the base value $x_B = x_{opt}$, $x_{max} > x_B > x_{min}$ and $x_i > x_B$

c_2/ $z_i = \dfrac{x_i - x_{min}}{x_B - x_{min}}$ if the base value $x_B = x_{opt}$, $x_{max} > x_B > x_{min}$ and $x_i < x_B$

d_1/ $z_i = \dfrac{x_{max} - x_i}{x_{max} - x_{B1}}$ if the upper base value $x_{B1} = x_{opt}$, $x_{max} > x_{B1} > x_{min}$ and $x_i > x_{B1}$

d_2/ $z_i = 1$ if $x_{B1} - x_{B2}$ is the optimal interval and $x_{B1} \geqslant x_i \geqslant x_{B2}$

d_3/ $z_i = \dfrac{x_i - x_{min}}{x_{B2} - x_{min}}$ if the under base value $x_{B2} = x_{opt}$, $x_{max} > x_{B2} > x_{min}$ and $x_i < x_{B2}$

The greatest difficulty in the practical application of these formula is presented by the scientific determination of the parameter range and of the optimum (best) parameter. Linearity is also only an assumption because it is difficult to demonstrate its existence, particularly around the limit values. If nonlinearity is unambiguous and the equation is known, the dimensionless numbers can then be taken from a table or a nomogram.

Determination of Weighting Factors for the Attributes as Well as for Groups of Attributes

The method of consulting specialists (Delphi-method) is suitable to specify weighting factors for the attributes selected and can be conducted in a relatively simple and inexpensive manner (Molnar 1984).

In the case of a large number of attributes this consultation method frequently presents requirements on the specialists' preference ability which can only be met with difficulties and inaccuracy. For this reason, the inaccuracy of the weighting factors assessed by this method or by direct ranking is often greater than the admissible level.

Random uncertainty is reduced if one proceeds not by A but by B, i.e., when the determination of the weighting factors

A	*B*
is conducted for all the attributes simultaneously, and the weighting factors of the groups and those within the groups of attributes are computed from the results.	is carried out within the groups of attributes, and those of the groups are determined separately.

The Guilford-method is applicable as well for the determination of weighting factors for attributes and for groups of them (Guilford 1936; Kendall 1970).

Computation of Overall Quality Index

Over and above the individually constructed mathematical equations applied to the various products, as a general rule, that qualimetric equation may be applied to any food product in which the overall quality is determined as a function of several variables of the different attributes (Molnar 1984).

$$Y = W_1 \sum_{j=1}^{k} w_{1j} \cdot x_{1j} + W_2 \sum_{j=k+1}^{l} w_{2j} \cdot z_{2j} + W_3 \sum_{j=l+1}^{m} w_{3j} \cdot z_{3j} + \ldots$$

where Y = overall quality index

W_1, W_2, W_3 .... weighting factors for groups of attributes whose sum being equal to 1 for every food product;

W_{1j}, W_{2j}, W_{3j} ... weighting factors for attributes within the same group, whose sum being equal to 1 for any food product within the same group;

z_{1j}, z_{2j}, z_{3j} .... normalized values between 0 and 1;

k, l, m .... number of attributes whose sum is n.

The scheme for calculation of the overall quality index is shown in Fig. 1.

It is also a general rule that the zero value of the "primarily critical" feature "eliminates" the calculated value of the overall quality index (Y). For food products, all characteristics are termed as "primarily critical" whose zero value indicates their harmfulness to health of their unfitness for human consumption. The sensory and microbiological attributes are generally ranged with the group of "primarily critical" ones.

Error of the Complex Evaluation Method

The random error involved in the investigation methods designed to measure attributes pertaining to the overall evaluation is also "transformed", which affects the accuracy of the overall quality index. By taking into consideration the weighting factors, these errors can be summarized through the variances, and thus the confidence interval of the overall quality index can be approximately computed. The first step was the calculation of the component variance for the groups of attributes:

$$\delta y_1 = \sqrt{\delta^2_{z11} \bullet w^2_{11} + \delta^2_{z12} \bullet w^2_{12} + \delta^2_{z13} \bullet w^2_{13} + \ldots}$$

$$\delta y_2 = \sqrt{\delta^2_{z21} \bullet w^2_{21} + \delta^2_{z22} \bullet w^2_{22} + \delta^2_{z23} \bullet w^2_{23} + \ldots}$$

$$\delta y_3 = \sqrt{\delta^2_{z31} \bullet w^2_{31} + \delta^2_{z32} \bullet w^2_{32} + \delta^2_{z33} \bullet w^2_{33} + \ldots}$$

where $\delta^2_{y1}, \delta^2_{y2}, \delta^3_{y3}$ variance of the normalized indices for the groups;
δ^2_{zij} variance of the normalized parameters for the attributes;
w_{ij} weighting factors for the attributes

$$\delta_Y = \sqrt{\delta^2_{y1} \bullet w^2_1 + \delta^2_{y2} \bullet w^2_2 + \delta^2_{y3} \bullet w^2_3 + \ldots}$$

where δ^2_Y variance of the overall quality index
W_1, W_2, W_3 weighting factors for the groups of attributes

Based on δ_Y at the chosen probability level (generally $\alpha = 0.05$) the errors of the overall quality index can be defined in the form a confidence interval.

DISCUSSION

The classification of food products into different quality classes is an important primary task of evaluation. In order to make classification possible, it is necessary to have an adequate division of the overall quality index ranging from 0 to 1. The experiences indicate that the specialists' judgements provide a right basis for the determination of class limits definitely within the range between 0 and 1. In the knowledge of the data series of several samples, the work of the specialists consists in performing the classification without prior calculation of the overall quality index. Review and command over five quality classes (excellent: 1; good: 2; mediocre: 3; satisfactory: 4; unsatisfactory: 5) may generally be expected from a specialist.

Between the average values of the quality classes given by the specialists and the overall quality index values calculated with the relevant weighting factors linear regression equations were computed by the method of least squares. The class limits expressed in the overall quality index (Y) were obtained by substituting the values 1.5, 2.5, 3.5 and 4.5.

In the case of the different evaluated products obtained thus far and of the calculated results, the following rounded up limit values are suggested for classification by the overall quality index:

0.800–1.000 excellent,
0.600–0.799 good,
0.400–0.599 mediocre,
0.200–0.399 satisfactory,
<0.200 unsatisfactory.

For the determination of the classification limits pattern recognition and other different mathematical methods e.g., discriminant and factor analysis are applicable (Holló *et al.* 1977). The scheme for the direct and "pattern recognition" based classification of food product quality is shown in Fig. 2.

Two basically different types of classification are conducted by the scheme outlined in Fig. 3.

The first phase is "learning" to which the empirically developed class limits are applicable. If enough knowledge is available, the quality class can be determined with sufficient reliability by pattern recognition.

A special type of the controlled classification methods is the Simca method (Holló *et al.* 1977) through which the model of "hyperboxes" enclosing the points of products belonging to the various classes is determined in the course of learning. Recognition itself means the investigation of whether the unified points of the attributes vector of a product of unknown class is located or not (outlier) in a certain hyperbox of some class in the principal component space. Based on the quality index currently used in food evaluation, this method is supposed to be directly utilizable in rendering class limit values more exact.

The other large group of pattern recognition methods is uncontrolled classification. In these methods, the classes are not known in advance, thus there is no product for which the quality class is known. The essence of cluster analysis applied in this case is that the possible classes (clusters) are inferred from the location of the product parameters in the space of essential attributes. Those products whose parameters are located "closely" together in the space of es-

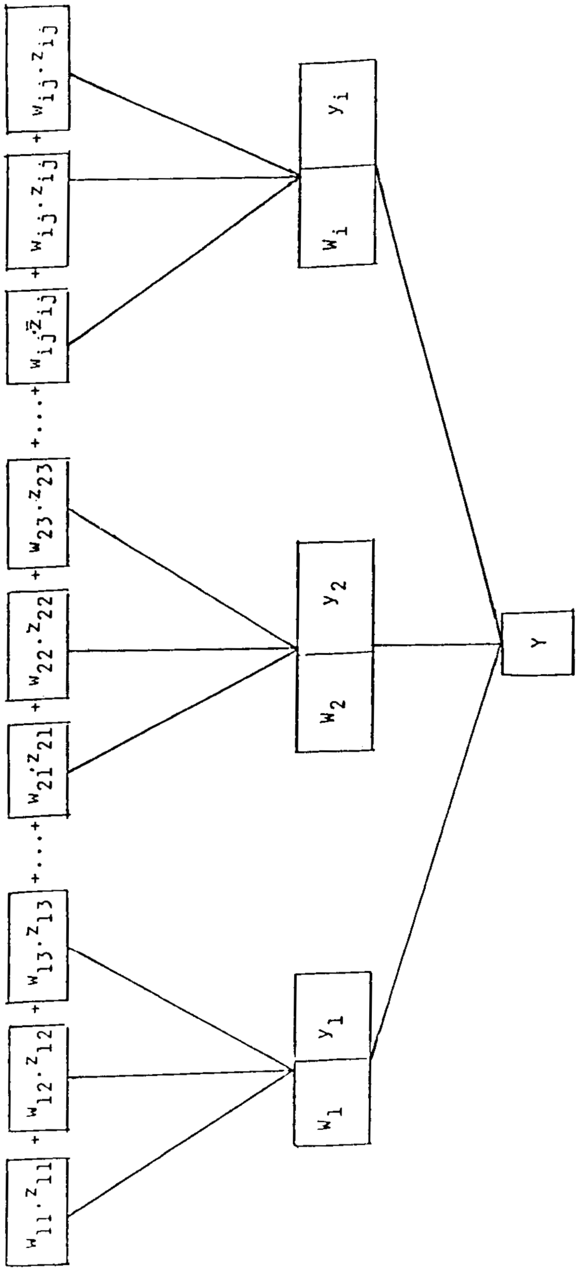

FIG. 1. SCHEME FOR CALCULATION OF THE OVERALL QUALITY INDEX

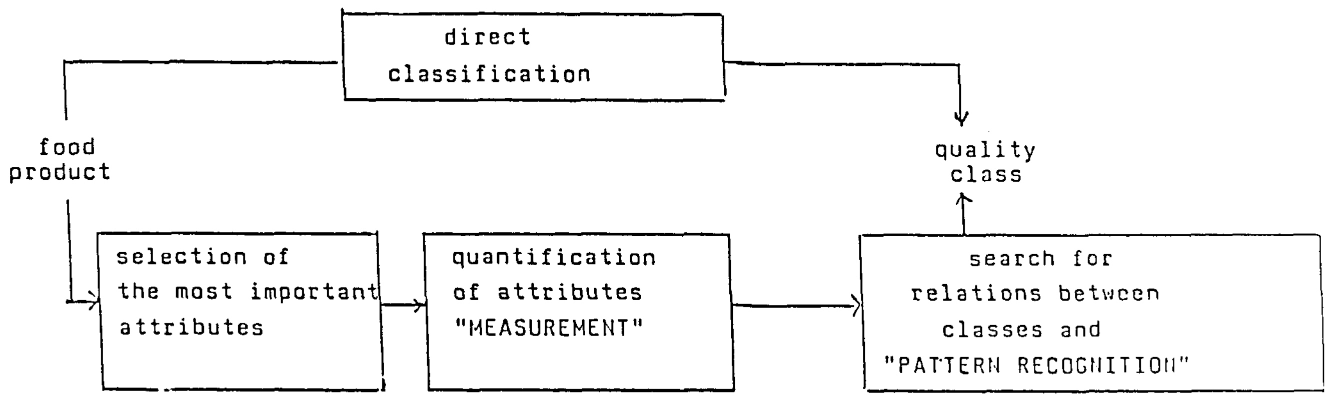

FIG. 2. DIRECT AND "PATTERN RECOGNITION" BASED CLASSIFICATION OF FOOD PRODUCT QUALITY

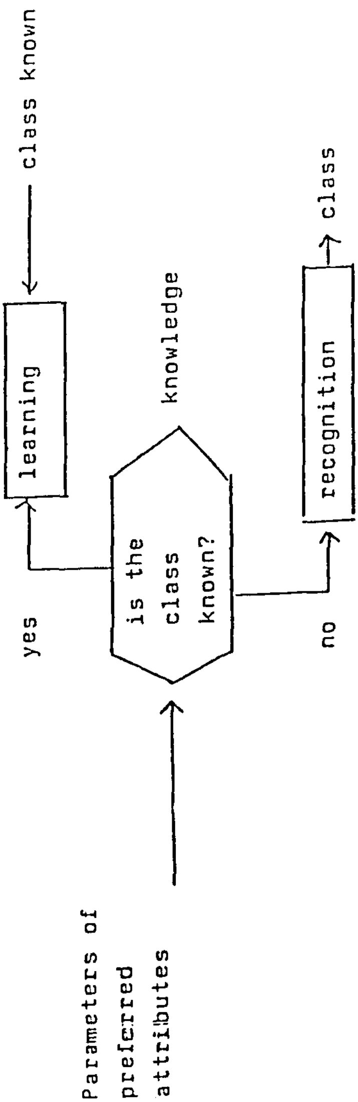

FIG. 3. SCHEME OF CONTROLLED CLASSIFICATION

sential attributes pertain to the same cluster whereas those whose parameters are widely "spaced" belong to different clusters. By applying this method, the suitability of the food testing method by quality index can be basically checked and a controlled classification can be formulated.

For most cases the statistical package for social sciences can be used for the statistical calculations (Bentel *et al.* 1978). Rosenfeld and Lea (1981) used parts of this model for the development of their quality indices. The multivariate data analysis introduced by many authors, e.g., by Martens *et al.* (1983) is mostly directed on the solution of some parts of overall food product evaluation, e.g., classification or regression, but they don't result in the numerical description of food quality.

Further development of scientifically founded and supported overall evaluation methods is a most timely task for synthesizing food research. This attempt is enhanced, among other things, by the general and increasing need for evaluation and classification of quality also on the part of the quality control.

In recent years despite extension and expansion of information related to different food products, methods that are sufficiently accurate, reproducible and conveniently feasible for measuring critical quality characteristics are not available. There is, therefore, an urgent need to develop overall evaluation programs for products or product groups.

In the course of implementing evaluation programs, the error in determination of the evaluation method is also subjected to further study. Calculations thus far indicate that the Gauss-type error determination will provide adequate information on the error of the overall quality index, whose magnitude imposes a limit on the maximum number of the classes as well. Presumably further calculations and studies will provide generalizable orders of magnitude for the errors pertinent to the various product groups if the error spread procedure proved to be suitable for error determination.

In relation to some of the products only preliminarily estimated limit values of classification are available. Should the general qualimetric equation values of classification be established in a unified way or is the use of separate limit values for each product group or even product more advisable? Experiences to date indicate that the limit values depend only to a minor extent on the magnitude of weighting factors and on the number of attributes or groups of attributes decisive for quality. For this and other practical reasons it appears to be more advisable and feasible to apply the alternative of unified limit values.

To develop and apply the overall evaluation method to various food products requires and presupposes multivarious and profound continued research. Significant progress can, therefore, be expected only if this synthesizing development work gains ground in international research and if the overall evaluation methods obtained for certain products, by using methods of pattern recognition, result in extendable experiences as far as a further development and practical application of the qualimetric equation is concerned.

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