ELSEVIER

0950-3293(94)00037-9

Food Quality and Preference 6 (1995) 185–190
Elsevier Science Limited
Printed in Great Britain.
0950-3293/95/$9.50+.00

A MODEL FOR OVERALL DESCRIPTION OF FOOD QUALITY

P. J. Molnár

Central Food Research Institute, Budapest, POB.:393, H-1536 Hungary

ABSTRACT

An index of food quality has been developed which is based on a weighted sum of individual quality parameters. These parameters assume normalized values between 0 and 1·0, with 0 representing the worst and 1 the best food quality. The total value of the weighting factors sums to 1. Different statistical methods, involving pattern recognition techniques, can be readily used for the continued development of the overall quality index. An example on fruit juice quality evaluation using the developed model is introduced.

INTRODUCTION

In preparing a well-founded comparison of the quality of several food products, the overall evaluation of food quality and its numerical description have increasing significance for product testing, product development and quality control.

The concept of food quality can be outlined as follows (Molnár *et al.*, 1979): the quality of food products, in conformity with consumer requirements and acceptance, is determined by their sensory attributes, chemical composition, physical properties, level of microbiological and toxicological contaminants, shelf-life, packaging and labelling. Within this model, food safety has primary significance for food quality, as shown in Fig. 1.

Another unique trait of food quality is the hierarchical and dynamic interactions of almost all of its attributes. For this reason, in formulating an evaluation system for food products, intercorrelations cannot be ignored.

From the above definition of food quality it also follows that quality is a convention developed by experts, and it may therefore be considered as constant over a limited period only. Beyond the absolute level of product characteristics, food quality is also dependent on the base values designated in specifications and norms. Variations in 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 attributes along a multivariate 'standard' scale or space.

MODEL DEVELOPMENT

Selection and grouping of attributes

Taking the definition of food quality as a starting point, the following groups of attributes are considered in evaluation:

- Sensory attributes
- Chemical composition and physical properties
- Microbiological contaminants
- Toxicological contaminants
- Packaging, labelling, as well as shelf-life, etc.

Within a group of properties, the type of product determines the attributes to be selected for consideration, based primarily on prior consultation with experts. This technical judgement is of importance even if mathematical methods are used to identify attributes. It is advisable to link the mathematical methods used in identifying attributes (e.g. principal component anaylsis) to the determination of the weighting factors for the selected attributes.

Possibilities of parameter normalization

In accordance with the evaluation methods, the range of parameters involved in the evaluation should be between 0 and 1. It is recommended that the limit values are chosen so as to have a 'sudden jump' in product quality at these values. The parameter ascribed to zero indicates a food product below the limit of acceptance and/or greatly differing from product specification. The optimum (best) value of the product parameter is ascribed to 1. The theoretical normalization model of measured parameters is as follows:

Parameter scale (x_j)		Scale of normalized parameters (z_j)
	best parameter	
x_{opt}		1·00
|		|
x_{worst}	parameter under limit of acceptance	0·00

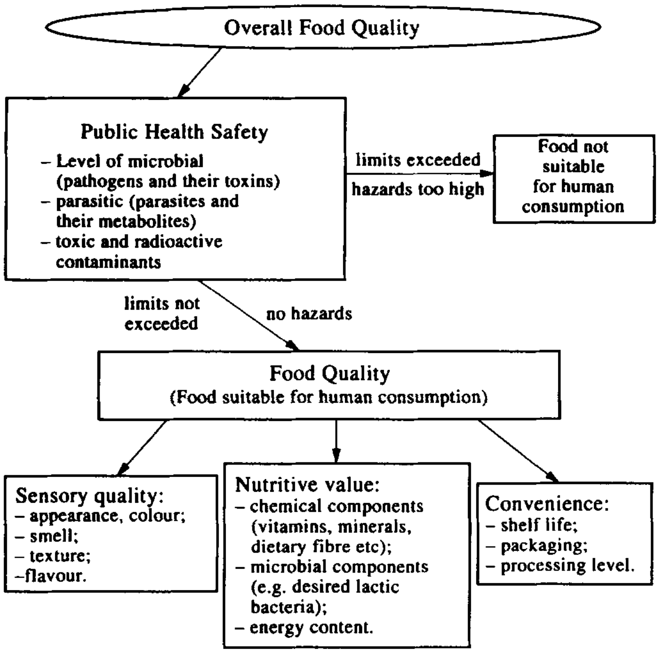

FIG. 1. Definition and description of food quality.

The relationship between the normalized and the original values is $z_i = f(x_i)$ which may be linear or nonlinear.

The linear transformation may be undertaken in accordance with several mathematical equations, e.g.:

$$Z_i = \frac{x_i - x_{min}}{x_{max} - x_{min}} \quad \text{if } x_{max} > x_1 > x_{min} \text{ and } x_{max} = x_{opt}.$$

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

Determination of weighting factors

The method of consulting experts (Delphi method) is suitable for specifying weighting factors for the attributes selected, and can be conducted in a relatively simple and inexpensive manner.

According to the Delphi method, each expert gets a questionnaire with the possible attributes identified and must estimate their importance on a per cent basis. One or two repetitions are conducted with or without declaration of the average and extreme values of the per cent estimates for each attribute. Corrections by the experts, on this basis, are allowed. A final plenary discussion can be conducted to obtain final values as weighting factors for each attribute.

If a large number of attributes is identified for one product it is not so easy to determine the weighting factors for each attribute exactly. Random uncertainty is reduced if one proceeds not by A but by B below, i.e. when the determination of the weighting factors:

A 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.

B 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 equation 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 or attributes (Molnár, 1984).

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

where

Y overall quality index

$W_1, W_2, W_3 \ldots$ weighting factors for groups of attributes whose sum is equal to 1 for each food product;

$w_{1j}, w_{2j}, w_{12} \ldots$ weighting factors for attributes within the same group, whose sum is equal to 1 for any food product within the same group;

$z_{1j}, z_{2j}, z_{3j} \ldots$ normalized values between 0 and 1;

$k, l, m \ldots$ number of attributes.

For food products, all characteristics are termed as 'primarily critical' whose zero value indicates their harmfulness to health and their unfitness for human consumption. This means that the Y value will be zero if one of the primarily critical attributes is zero. This product is, of course, not suitable for human consumption.

The sensory and certain microbiological attributes (e.g. pathogenic micro-organisms) are generally ranged with the group of 'primary critical' ones. Several sensory defects (e.g. fermented fruit juice or rancid fats) are primarily critical, which means that any product with the defect must get zero as its overall quality index.

The random error in the overall evaluation method can be calculated, which depends on the investigation methods for each attribute.

Classification of food products using the overall quality index

The classification of food products into different quality classes is an important task. In order to make classification possible, it is necessary to have an adequate division of the overall quality index ranging from 0 to 1. Experience indicates that experts' judgements provide a valid basis for the determination of class limits

TABLE 1. General Classification Limits

Class	Description	Limits
I	excellent	0·800–1·000
II	good	0·600–0·799
III	mediocre	0·400–0·599
IV	satisfactory	0·200–0·399
V	unsatisfactory	<0·200
VI	not for human consumption	0·000

within the range between 0 and 1. The work of the experts consists in performing the classification without prior calculation of the overall quality index. Review and command over five quality classes (excellent: 5; good: 4; mediocre: 3; satisfactory: 2; unsatisfactory: 1) may generally be expected from an expert.

Between the average values of the quality classes given by the experts and the overall quality index values calculated with the relevant weighting factors, linear regression equations were computed by the methods 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. The first calculations indicated a suitable correspondence between predicted values and expert judgements for some fruit

TABLE 2. Evaluation Model for Blackcurrent Nectar

Attributes Group	Attribute	x_{opt}	x_{worst}	Tolerance Values	Transformation Equation	Remark
1 Sensory Attributes	1·1 Colour (Score) 1·2 Appearance (Score) 1.3 Smell (Score) 1.4 Flavour (Score)	5·0	1·8	1·8 to 5·0	$z_1 = \frac{x_1 - 1{\cdot}8}{3{\cdot}2}$	For all sensory attributes
2 Physical and Chemical Attributes	2·5 Relative Density 20/20°C	1·060	<1·055	1·055 to 1·065	$z_{51} = \frac{x_5 - 55}{5}$ at $x_5 \leq 60$ $z_{52} = \frac{65 - x_5}{5}$ at $x_5 \geq 60$	For transformation in Oechsle
	2.6 Titrable Acid in g/l (pH 7·0) calc. as Wine Acid	10·0	<8·0	8·0 to 11·0	$z_{61} = \frac{x_6 - 8}{2}$ at $x_6 \leq 10$ $z_{62} = 11 - x_6$ at $x_6 \geq 10$	
	2.7 Alcohol in g/l	1·0	>3·0	0·0 to 3·0	$z_7 = \frac{3{\cdot}0 - x_7}{2}$	
	2.8 Volatile acid in g/l calc. as Acetic Acid	0·2	>0·3	0·0 to 0·3	$z_8 = \frac{0{\cdot}3 - x_8}{0{\cdot}1}$	
	2.9 Vitamine C in mg/l	370	<200	200 to 370	$z_9 = \frac{x_9 - 200}{170}$	
	2.10 Sugar–Acid Ratio	5·9	<4·9 >7·9	4·9 to 7·9	$z_{10{\cdot}1} = \frac{x_5}{x_6} - 4{\cdot}9$ at $\frac{x_5}{x_6} \leq 5{\cdot}9$ $z_{10{\cdot}2} = \frac{7{\cdot}9 - \frac{x_5}{x_6}}{2}$ at $\frac{x_5}{x_6} \geq 5{\cdot}9$	
3 Other Attributes	3.11 Microbial Attributes (Score)	5·0	1·8	1·8 to 5·0	$z_{11} = \frac{x_{11} - 1{\cdot}8}{3{\cdot}2}$	For Z_{12} the same transformation
	3.12 Packaging and Labelling (Score)					

TABLE 3. Sample A of High Quality

Attributes Group i	Attributes j	x_{ij}	z_{ij}	w_{ij}	Y_i	W_i	Y
1 Sensory Attributes	1.1 Appearance	5·0	1·00	0·15			
	1.1 Colour	5·0	1·00	0·25			
	1.3 Smell	5·0	1·00	0·20	0·98	0·60	
	1.4 Flavour	4·8	0·94	0·40			
2 Physical and Chemical Attributes	2.5 Relative Dens.	59	0·80	0·10			
	2.6 Titrable Acid	10·6	0·40	0·10			
	2.7 Alcohol	0·5	1·00	0·15			0·94
	2.8 Volatile Acid	0·12	1·00	0·15			
	2.9 Vitamine C	360	0·94	0·30	0·84	0·30	
	2.10 Sugar/Acid	5·6	0·70	0·20			
3 Other Attributes	3.11 Microbial Attributes	5·0	1·00	0·50			
	3.12 Packaging and Labelling	5·0	1·00	0·50	1·00	0·10	

TABLE 4. Sample B of Low Quality

Attributes Group i	Attributes j	x_{ij}	z_{ij}	w_{ij}	Y_i	W_i	Y
1 Sensory Attributes	1.1 Appearance	5·0	1·00	0·15			
	1.1 Colour	2·6	0·25	0·25			
	1.3 Smell	2·5	0·22	0·20	0·34	0·60	
	1.4 Flavour	2·5	0·22	0·40			
2 Physical and Chemical Attributes	2.5 Relative Dens.	59	0·80	0·10			
	2.6 Titrable Acid	10·0	1·00	0·10			
	2.7 Alcohol	2·0	0·50	0·15			0·47
	2.8 Volatile Acid	0·25	0·50	0·15			
	2.9 Vitamine C	286	0·51	0·30	0·68	0·30	
	2.10 Sugar/Acid	5·9	1·00	0·20			
3 Other Attributes	3.11 Microbial Attributes	5·0	1·00	0·50			
	3.12 Packaging and Labelling	5·0	1·00	0·50	1·00	0·10	

juices and bakery products (Molnár and Örsi, 1982). For the determination of the classification limits, pattern recognition and other mathematical methods, e.g. discriminant and factor analysis, are also applicable.

In the case of the different products evaluated so far, the following rounded limit values can be used for classification by the overall quality index.

Application for the evaluation of blackcurrent nectar

As an example, the evaluation model for blackcurrent nectar should be introduced (see Table 2). Table 3 indicates calculation example for high quality and Table 4 the same for low quality. Table 5 contents the classification results for both samples.

TABLE 5. Classification of the Quality of Both Samples

Sample	Y	Quality class
A	0·940	'Excellent'
B	0·470	'Mediocre'

CONCLUSION

(1) An overall quality index calculated in accordance with a previously developed theoretical model is suitable for the numerical description of food quality. Further development of scientifically sound 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.

(2) The classification of food products into different quality classes is an important 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. For the exact determination of the classification limits concerning product groups, pattern recognition and several other mathematical methods (e.g. discriminant and factor analysis) can be used in addition to the Delphi method.

(3) To develop and apply the overall evaluation method to various food products requires continued research.

Significant progress can be expected only if this development work gains ground in international research and standardization, and if the overall evaluation methods obtained through pattern recognition result in useful data as far as further development and practical application of the qualimetric equation is concerned. The applicability of the developed model for storage experiments and for prediction of product quality should be investigated using suitable data from several foods.

REFERENCES

Guilford, J. P. (1936). *Psychometric Methods.* McGraw-Hill Books, New York.

Kendall, M. G. (1970). *Rank Correlation Methods.* Griffin, London.

Molnár, P., Vajda, Ö. & Dzur, K. (1979). Comparative study of food evaluation methods. *Proc. 23. Conference of the European Organization for Quality Control,* Food Seminar, No. 113. Budapest, Hungary, pp. 17–30.

Molnár, P. (1984). The design and practical use of an overall quality index for food products. *Acta Alimentaria,* **13**, 215–28.

Molnár, P. & Örsi, F. (1982). Determination of weighting factors for the sensory evaluation of food. *Die Nahrung,* **26**, 661–7.

Rosenfeld, H. J. & Lea, P. (1981). Quality index for vegetables. *Proc. II. International Symposium on Vegetable Quality,* Tiraspol, Italy, pp 18–23.

COMMENTARIES

Molnár's paper, which concerns the development and application of a quantitative model for the prediction of food quality, raises several interesting issues that strike at the heart of food quality assessment. These issues concern (1) the unitary vs. multivariate nature of food quality, (2) the role of experts vs. consumers in quality assessment, and (3) synthetic vs. analytic approaches to understanding quality.

Unitary vs. multivariate nature of food quality

As it relates to the unitary vs. multivariate nature of food quality, Molnár's paper beautifully underscores the essence of the problem. From both a conceptual and empirical standpoint, the approach outlined by Molnár assumes that food quality is a multivariate phenomenon. That is, it assumes that there exists a series of chemical, sensory, microbiological, and other characteristics of the product that comprise overall quality, and that each of these characteristics can be independently measured and then composited to index overall quality. However, the very fact that the model attempts to generate an overall index of food quality belies another assumption—that at some different level of analysis, food quality is really a unitary phenomenon, and that disparate products can be placed along a single continuum of good–bad quality. This dualistic view of the conceptual nature of food quality is evident in most attempts to model food quality and is a major contributing factor to the diversity of opinion and approaches for assessing food quality in the industry today.

From the consumer's perspective, food quality is certainly a unitary concept. When asked about the quality of a particular food item, the consumer does not pause, separate, and analyze all of the individual factors that may be contributing to his/her perception of the quality of the item. This is because humans are wonderfully adept at providing integrated responses to what appear to be, upon reflection, complex judgemental processes. In light of this unique ability, it is easy to understand why many researchers (e.g. Steenkamp, 1986; McNutt, 1988; Fishken, 1990; O'Mahony, 1991; Cardello, 1993, 1994*a,b*) place heavy emphasis on consumer judgements as a direct and practical measure of what is meant by a product's quality (quality as the degree of excellence of the product). Molnár's own definition of food quality acknowledges this reliance of food quality assessment on consumer opinion, as is reflected in his phrase 'in conformity with consumer requirements and acceptance.' Unfortunately, neither in the model he presents nor in the methodology for assessing quality is the consumer again mentioned. Molnár's entire approach to food quality is dependent upon direct expert judgements of either the product itself or of the importance of various instrumental and/or chemical data to the product's quality.

While my own opinions and approach to food quality are quite different from those outlined by Molnár, I will not belabor the issue of consumer vs. expert opinions of food quality, since this point is adequately discussed in other papers in this volume. Instead, it would be worthwhile to consider the methods that are used to arrive at numerical weightings and to generate the overall quality index.

Parameter weightings

Stated generally, Molnár's approach identifies a set of chemical, instrumental, sensory, and other variables that contribute to a product's overall quality. These variables are then quantified, and weightings are assigned by experts to index their relative importance to the product's quality. The weighted values are then integrated to arrive at a total quality index for the product. However, the approach appears to utilize a mix of subjective and/or synthetic methods and statistical/analytic procedures for identifying important variables and establishing their weightings. On the one hand, Molnár emphasizes the important role of the expert in identifying these attributes and establishing their weightings using the Delphi method. This latter method consists of a loosely defined set of procedures for arriving at a consensus among a set of experts 'when accurate information is unavailable or expensive to obtain, or evaluation models require subjective inputs to the point where they become the dominating parameters' (Linstone & Turoff, 1975). In essence, this method provides subjective data and numerical values that can be incorporated into the model in a synthetic approach to modeling quality. On the other hand, Molnár also stresses the importance of statistical analysis (pattern recognition, PCA, etc.) in identifying and weighting these factors. How these disparate forms of data are integrated to arrive at final parameter values for the model is left unstated.

A second problem with the model arises with the need to identify optimal and worst parameter values in order to normalize the absolute values on each parameter. Certainly, even experts will disagree on the optimal value of a given parameter to produce the highest quality in the product. Molnar acknowledges this problem in the text, and further work on reducing this obvious source of variability in the model is necessary.

Validity criteria

The last issue of some concern relates to the validity criterion that should be applied to the model. While the mathematics of the model will undoubtedly result in a predicted index of a product's overall quality, what is the validity criterion against which the predictions can be compared? Given that the method relies on expert opinion, one obvious validity criterion is the experts' own judgements of the overall quality of the items tested. While it is suggested that such classifications are done as part of model development, empirical data on post-development validity tests would be worthwhile. Similarly, since the intent of the model is to predict food quality for purposes of both quality control and product improvement, alternative predictive validity criteria, e.g. consumer opinions of product quality, should be examined.

In spite of the above shortcomings, Molnár's model is a significant step forward in the quest to uncover the factors important to food quality and to develop a quantitative method to integrate these factors in a predictive manner. The model reflects both the progress made to date in understanding these factors, as well as the areas where continued research is necessary.

Armand Cardello

REFERENCES

Cardello, A. V. (1993). Sensory quality. *Cereal Foods World*, **38**, 435–9.

Cardello, A. V. (1994*a*). Consumer perception of food quality. In *Quality Preservation in Food Storage and Distribution*, ed. I. Taub & P. Singh. The American Chemical Society, Washington, DC, (in press).

Cardello, A. V. (1994*b*). Food quality: Relativity, context and consumer expectations. *Food Qual. Pref.*, (in press).

Fishken, D. (1990). Sensory quality and the consumer: Viewpoints and directions. *J. Sensory Studies*, **5**, 203–9.

Linstone, H. A. & Turoff, M. (1975). *The Delphi Method: Techniques and Applications*, Addison-Wesley, Reading (MA), p. 10.

McNutt, K. (1988). Consumer attitudes and the quality control function. *Food Technol.*, **42**, 97–108.

O'Mahony, M. (1991). Taste perception, food quality and consumer acceptance. *J. Food Qual.*, **14**, 9–31.

Steenkamp, J. B. E. M. (1986). Perceived quality of food products and its relationship to consumer preferences: Theory and measurement. *J. Food Qual.*, **9**, 373–86.

- The definition of 'quality' and its evolution is appropriate and well-described.
- I wonder if this method allows us to assign different weight to the attributes and the attribute groups. For example, sensory attributes might be more relevant for a given product than chemical attributes would be.
- The conclusions are also good, especially point 3, as there is need for international research and standardization. However, will this research and standardization be possible at a global level, or must a common legal harmonization first be achieved?
- How can we take into account the evolution in the perception of quality?

L. Bertozzi