FOOD QUALITY INDICES

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Summary

The quality of food products, in conformity with consumer requirements, is determined by sensory attributes, chemical composition, physical properties, the level of microbiological and toxicological contaminants, and shelf life, and by packaging and labeling. Another unique trait of food quality is the hierarchical and dynamic interrelation of almost all its attributes. For this reason, the investigation of interrelated effects should be remembered when formulating an evaluation system for food products.

From the definition of quality, we understand that quality is an arbitrary term, a matter of convention, and it may therefore be considered as constant over a short period only,

and that, beyond the absolute level of product characteristics, it is also dependent on the base values designated in specifications or norms. The variation of product characteristics determines 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 *etalon*, which means the location of the parameters of the product along a multivariate standard scale or space.

For the numerical description of food quality, evaluation methods with so-called quality indices have been introduced. These indices provide a framework for development of methods necessary for overall food evaluation necessary in both quality control and product development. Food research has revealed new knowledge of 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, have provided a 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. The transformed values are then weighted and summarized.

1. Introduction

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

To formulate an evaluation pattern, the concept of food quality is outlined as follows. 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, and shelf life, and by 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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methods necessary for overall food evaluation necessary in both quality control and product development. Food research has revealed new knowledge of 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 have provided a means of calculation not previously practical.

Every food product has characteristics and indices measurable by sensory, physical-chemical, or microbiological methods. Some characteristics are easily perceived; others are unseen. Understanding these quality characteristics and being familiar with the appropriate measuring tools are vital to quality control and the quality assurance of food products.

2. Factors Determining Food Quality

2.1. Sensory Properties

The measurement of sensory properties and determination of the importance of these properties to consumer product acceptance represent major accomplishments in sensory evaluation. These achievements have been possible as a direct result of advances in sensory evaluation, in the application of contemporary knowledge about the measurement of human behavior, and in a more systematic and professional approach to testing.

Man accepts food on the basis of certain characteristics that he defines and perceives with his senses. These attributes are described in terms of sensations and are sometimes referred to as qualitative or sensory qualities. They include perceptions of appearance factors such as color, size, shape, and physical aspects; kinesthetic factors such as texture, viscosity, consistency, finger feel, and mouth feel; and flavor factors or sensations combining odor and taste.

2.1.1. Appearance and Color

Color and other aspects of appearance influence food appreciation and quality, especially by the consumer. Man has subjective standards for the acceptable range and preferred optima for these qualities for almost every food.

The importance of the color of agricultural commodities and processed foods cannot be overstressed. An important problem is discoloration or the fading of the colors of various raw and processed fruits and vegetables. In some cases, color changes are accompanied by undesirable changes in texture, taste, or odor. Overaged cheese, beer, meat, and fish all develop off-color, which the consumer recognizes as being associated with poor flavor quality. The maturity of many fruits and vegetables is closely associated with color development or changes in color. In other cases a color change may not be actually detrimental, but nevertheless reduces consumer acceptance. Consumers expect certain foods to have certain colors, and deviation from those colors may cause sales resistance. Many of these prejudices are altogether irrational. When natural carotene content is low, butter is artificially colored; mint-flavored ice cream is

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white before artificial green coloring is added; orange sherbet is also fortified with artificial coloring. Maraschino cherries, oranges, syrups, jellies, and many types of candy are artificially colored.

Five functions that should be considered in understanding human reactions to color in foods are listed below:

- Perception. Food selection or judgment of food quality would be extremely difficult if color discrimination were removed, even though size, texture, shape, and other cues were left intact.
- Motivation. Food color and the color of the environment in which the food is seen can significantly increase or decrease our desire or appetite for it.
- Emotion. Liking or disliking a food is conditioned by its color; attractive foods are sought out as pleasure-giving, while unattractive foods are avoided.
- Learning. By the process of experience, we learn what color to expect and consider "natural," and we predict rather precisely what properties a food or beverage will have from our memory of similar materials.
- Thinking. Our reaction to unusual properties or to new foods can be changed if they are explained to us.

Obviously, far too little is known about the significance of color perception in food acceptance. Observers do associate certain colors with acceptance, indifference, or rejection. Colored lights are used to mask color differences and reduce some influence of color on sensory evaluation, but the psychological effect of colored lights has not been adequately measured. These effects may be direct, on the appeal of the food as a whole, or indirect, in influencing odor, taste, or texture thresholds. Various interrelationships suggest themselves.

The human eye has a remarkably fine qualitative discrimination for color, but is not a quantitative instrument. Consequently, precise color measurement requires modern instruments. This need is felt particularly where food products are blended to a certain standard from raw materials that differ somewhat in their color properties, such as with tomato catsup. The effect of climate and time of harvesting have a marked influence on the color of the raw material from which many processed foods are made.

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2.1.2. Texture

Texture can be described as the properties of a foodstuff apprehended both by the eyes and by the skin and muscle senses in the month, embracing roughness, smoothness, graininess, and so forth.

The texture or mouth feel of liquid foods, especially those that behave as Newtonian fluids, is closely related to their viscosity. When the degree of gum solution sliminess was evaluated by a trained panel, mouth feel ratings were correlated with viscosity.

The texture of fruits and vegetables has been assessed with instruments that measure compression, resistance to penetration, or force required to shear. The Magness pressure tester, wherein a steel plunger of a specified diameter penetrates the flesh of a fruit, is used widely for determination of the maturity of deciduous fruits. Various penetrometers have been developed for objective evaluation of the texture of cooked, canned, and frozen foods.

With peaches, a number of investigators have shown that texture is an important aspect of consumer acceptance, and that pectin changes are related to textural changes. Protopectin is converted to water-soluble pectin during ripening, thus causing softening. Reduction of processing time lowers the retention of protopectin, and hence the firm texture in both cling and freestone peaches.

The most important components of food texture are indicated in Table 1.

Mechanical Properties	**Geometrical Properties**	**Moisture Properties**
– Hardness: • Firm (compression) • Hard (lite) – Cohesiveness: • Cohesive • Chewy • Fracturable (crispy/crunchy) – Adhesiveness: • Sticky • Smooth – Denseness: • Dense/heavy • Airy/puffy/light – Springiness: • Springy/rubbery	– Smooth – Gritty – Grainy – Chalky/powdery – Fibrous – Lumpy/bumpy	– Juicy – Oily – Greasy

Table 1. Components of texture

2.1.3. Taste and Flavor

When food is consumed, the interaction of taste, odor, and textural feeling provides an overall sensation that is best defined by the English word "flavor." German and some other languages do not have an adequate expression for such a broad and comprehensive term. Flavor results from compounds that are divided into two broad classes: Those responsible for taste and those responsible for odors, the latter often designated as aroma which provides both sensations.

Flavor is the most important sensory property of many food products. Flavor, as an attribute of foods, beverages, and seasonings, is defined as the sum of perceptions resulting from stimulation of the sense ends that are grouped together at the entrance of the alimentary and respiratory tracts. For the purpose of practical sensory analysis, the term for the impressions perceived via the chemical senses from a product in the mouth is restricted. Defined in this manner, flavor includes:

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- Odor, the olfactory perception caused by volatile substances released from a product in the mouth via the posterior napes
- Taste, gustatory perceptions (salty, sweet, sour, bitter) caused by soluble substances in the mouth
- Chemical feeling factors that stimulate nerve ends in the soft membranes of the buccal and nasal cavities (astringency, spice heat/cooling, bite, metallic flavor, umami taste).

Compounds responsible for taste are generally nonvolatile at room temperature. They interact only with taste receptors located in the taste buds of the tongue.

Aroma substances are volatile compounds that are perceived by the odor receptor sites of the smell organ, the olfactory tissues of the nasal cavity. The concept of aroma substances, like the concept of taste substances, should be used loosely, since a compound might contribute to the typical odor or taste of one food, while in another food, it might cause a faulty odor or taste, or both, resulting in an off-flavor.

The lowest concentration of a compound that can still be directly recognized by its odor is designated as an odor threshold. Threshold concentration data allow comparison of the intensity or potency of odorous substances. The examples in Table 2 illustrate that great differences exist between individual aroma compounds, with an odor potency range of several orders of magnitude.

The threshold concentrations (values) for aroma compounds are dependent on their vapor pressure, which is affected by both temperature and medium. The values are also influenced by the assay procedure and/or performance of the sensory panel. The frequent discrepancies in threshold values in the literature are basically due to such differences.

Compound	**Threshold value (mg/l)**
Pyrazine	300.00
Ethanol	100.00
Maltol	35.00
Hexanol	0.7
Butyric acid	0.2
Vanillin	0.02
Limonene	0.01
Linalool	0.006
Hexanal	0.0045
2-Phenylethanal	0.004
α-Ionone	0.004
2-Methylpropanal	0.001
Ethylbutyrate	0.001
(+)-Nootkatone	0.001

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(-)-Nootkatone	1.0
2-Methylbutyric acid ethyl ester	0.0001
4-Hydroxy-2,5-dimethyl-3(2H)-furanone	0.00004
4-Methoxy-2,5-dimethyl-3(2H)-furanone	0.00003
Methylmercaptan	0.00002
β-Damascone	0.000009
β-Ionone	0.000007
2-Isobutyl-3-methylpyrazine	0.000002
1-p-Menthen-8-thiol	0.00000002

Table 2. Odor threshold values of some aroma compounds in water at 20 ˚C

The amount of volatile substances in food is exceptionally low, generally only 1 mg/kg to 50 mg/kg. However, their number reaches several hundreds. Not all of these are important to food aroma. For an aroma compound to be perceived, a component of the volatile fraction must be present in food in higher concentration than its threshold value. The discrimination of the aroma constituents from the other volatile compounds is often difficult, and usually provides only approximate values at best. Particularly important aroma constituents are those compounds that bear the characteristic aroma of the food, the so-called "character impact compound." With regard to the occurrence of such key compounds, food can be divided into four groups:

- Group 1: The aroma is decisively carried by one compound. The presence of other aroma compounds serves only to round off the characteristic aroma of the food.
- Group 2: Several compounds, one of which may play a major role, create or determine the typical aroma of the food.
- Group 3: The aroma may be closely simulated or reproduced only with a large number of compounds not present.
- Group 4: The food aroma cannot be satisfactorily reproduced even with a large number of volatile compounds.

Examples of all four groups outlined above exist among fruit and vegetable aromas. Butter and blue cheese aromas are decisively formed by 2,3-butanedione and supported by acetaldehyde and dimethylsulfide or by 2-heptanone and 2-nonanone, respectively, and are suitable examples of Group 2.

Food aroma obtained by a thermal process, alone or in combination with a fermentation process, is highly complex in its composition. This aroma should belong to Group 3 (processed meat, roasted coffee, tea, or bread), or to Group 4 (cocoa or beer).

A strange, extraneous type of aroma, normally not present in a food, may arise through loss of "impact compounds," or a shift in aroma concentration, or a change in composition of the individual components of the aroma. This is designated as an aroma defect, or simply as an off-flavor. Some common off-flavors that can arise during food

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processing and/or storage are listed in Table 3.

Food product	Off-flavor
Milk	Sunlight flavor
Milk	Bean-like, gluey, glutinous
Milk fat	Metallic
Milk products	Malty
Mutton-meat	Sweet, acidic
Peas, deep frozen	Hay-like
Orange juice	Grapefruit note Terpene note
Beer	Sunlight flavor Phenolic note

Table 3. Off-flavors in food products

The application of modern analytical instruments to problems of food science has been rapid and extensive, primarily because of the sensitivity of the instruments to small amounts of volatile material. Although they will probably be used more in investigations of the composition of foods, we can also expect application in detecting off-odors, and of the correlation between the amounts of specific compounds and sensory quality. It has been noted that, in some cases, it appears that compounds present in subthreshold concentrations exhibit a synergistic effect, and thus contribute to the odor of the food.

2.2. Physical Properties

Among physical properties playing a role in the determination of food quality, the appearance, color, and texture are primary.

Appearance. The size and shape of food products, together with defects and color, are appearance factors that greatly influence initial consumer impressions. Unfortunately, these sensory attributes are often taken for granted or even overlooked. Appearance factors are also useful in sizing and grading, which ensure uniformity and facilitate the process of buying and selling. During food manufacture, grading according to size shortens the succeeding processing operations and improves the quality of the endproduct.

Color is a quality factor that greatly influences the appearance of a product. Associated with it are several desirable and undesirable changes in food, such as those occurring during ripening, storage, curing, spoilage, and so on. Color is a character of light, measurable in terms of intensity and wavelength. It is a general term for all sensations arising from the activity of the human eye. When light reaches the retina it sensitizes the nerve mechanisms.

The physical tests commonly used for color measurement are the spectrophotometric and the Munsell systems. Each is a tri-stimulus system in which color is specified by

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three attributes; dominant wavelength, purity, and lightness in the spectrophotometric systems; hue, chroma, and value in the Munsell system. Of the two, the latter is more popular because of its simplicity and low cost.

Some other physical properties may be also of importance in quality evaluation of specific foods. Volume is interesting for baked products; textural properties for meat products. Tenderness of meat is an important quality index. Specific gravity measurement is used for the detection of watered milk.

2.3. Chemical Composition

The nature and amount of substances in a given food product determine the nutritive value and other properties. As the development and enforcement of standards of identity and purity, the control of food safety is based on the determination of chemical composition, including chemical contaminants. Analysis of the molecular composition of food substances is known as proximate analysis. It is used to study the protein, fat, carbohydrate, ash, and water content of foods (see *Food Quality and Assurance*).

2.3.1. Moisture Content

Water (moisture) is the predominant constituent in many food products (Table 4). As a medium, water supports chemical reactions, and it is a direct reactant in hydrolytic processes. Therefore, removal of water from food, or binding it by increasing the concentration of common salt or sugar retards many reactions and inhibits the growth of microorganisms, thus improving the shelf life of a number of foods. Through physical interaction with proteins, polysaccharides, lipids, and salts, water contributes significantly to the texture of food.

Product	Moisture Content (g/100g)	Product	Moisture Content (g/100g)
Meat	65–75	Butter	16–18
Milk	87	Margarine	16–18
Fruit	70–90	Cereal flavor	12–14
Vegetables	70–90	Coffee beans, roasted	5
Bread	35	Milk powder	4
Honey	20	Edible oil	0

Table 4. Moisture content in some food products

Water activity (a_w) (see *Food Quality and Assurance*) influences the storability of foods. Decreased water activity retards the growth of microorganisms and slows enzyme-catalyzed reactions (particularly involving hydrolyses).

The storage stability of food with a_w between 0.2 and 0.4 is the highest. This a_w range obviates the need for preservatives against microbial spoilage, and food quality is

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unaffected by nonenzymatic browning and lipid auto-oxidation, because these reactions are essentially prevented.
Food products with a_w values between 0.6 and 0.9 are known as "intermediate moisture foods." These food products must be protected extensively against microbial spoilage. One of the options to decreasing water activity, and thus improving the shelf life of food, is to use additives with high water-binding capacities (humectants).

2.3.2. Fat Content

The majority of lipids are derivatives of fatty acids. In these so-called acyl lipids the fatty acids are present as esters and in some minor lipid groups in amide form. The acyl residue influences strongly the hydrophobicity and the reactivity of the acyl lipids.

Some lipids act as building blocks in the formation of biological membranes that surround cells and subcellular particles. Such lipids occur in food products, but usually at less than 2%. Nevertheless, even as minor food constituents, they deserve particular attention, because their high reactivity may strongly influence the sensory quality of food.

The fats deposited in some animal tissues and the organs of some plants are primarily triglycerides. Lipid content in such storage tissues can rise to 15% to 20% or higher, and so serve as a commercial source for isolation of triglycerides. When this lipid is refined, it is available to the consumer as edible oil or fat.

The nutritive, physiological importance of lipids is based on their role as fuel molecules (39 kJ/g triglycerides), and as a source of essential fatty acids and vitamins. Apart from their roles, some other lipid properties are indispensable in food handling or processing. These include the pleasant creamy or oily mouthful, and the ability to solubilize many taste and aroma constituents of food.

These properties are of importance for food to achieve the desired texture, specific mouthful, and aroma, with satisfactory aroma retention. In addition, some foods are prepared by deep-frying—by cooking the food in fat or oil heated to a relatively high temperature.The lipid class of compounds also includes some important food aroma substances or precursors that degrade, providing the aroma compounds that are indispensable as food emulsifiers, while others are important as fat-soluble or oil-soluble pigments or food colorants.

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Biographical Sketch

Dr. Pál J. Molnár is Scientific Advisor and Director of the Food Quality Center in the Central Food Research Institute in Budapest. He studied Food Technology and Biochemistry at Humboldt University of Berlin during 1962–1966. He received his Ph.D. from the same university in 1972, and his D.Sc. from the Hungarian Academy of Sciences in 1996. His main activities are related to food quality, sensory analysis of food, and several fields of food quality management, including food standardization and product development. He is President of the Hungarian National Committee of the European Organization for Quality (EOQ) and co-chairman of the Codex Alimentarius Commission on Methods of Analysis and Sampling (CCMAS), and has several other national and international positions. He is Editor of the Hungarian scientific periodical *Élelmiszervizsgálati Közlemények* (Food Investigations).
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