FRUITS AND VEGETABLES

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Summary

Quality determination of fruits and vegetables is at present characterized by the overwhelming use of sensory evaluation. Quality indices include primarily external properties, such as appearance, size, shape, color, texture, and flavor. In addition, there is content control, mainly in the processing industry, of some chemical components (N-containing compounds, carbohydrates, and so on), and packaging and labeling controls.

Conformity with relevant product standards is also an important requirement that is inspected for the trade of fruits and vegetables. A new approach to describe fruit and vegetable quality by an overall evaluation method provides numerical values that could be used for their classification in the future.

The most important quality characteristics of selected fruit and vegetable varieties (apples, apricots, cherries, peaches, oranges; potatoes, carrots, green beans, peas, and tomatoes) are also briefly treated in the framework of this chapter.

1. Introduction

The desirable characteristics of a fruit or vegetable are dictated largely by the market for which it is intended, and by the use to which it will be put. Traditionally, the fresh market is the one to which the grower turns, and to secure an immediate and ready sale for his produce, he tends to give priority to size and eye appeal. Only rarely do the same properties commend themselves to the food manufacturer seeking raw material for industrial transformation or preservation.

It was once supposed that fruits and vegetables unsuitable for direct retail markets because of unattractive size or shape, or blemish, would provide raw material for food manufacture, but this is not generally true. Quite apart from the important chemical differences that occur between varieties and materials at different stages of maturity, it has been found that a good quality manufactured article cannot be made from poor quality raw material.

With the increased rate of production, uniformity of size, shape, and composition have become important, and specifications for raw materials for canning and freezing, for example, are now more exacting than specifications for sale on the fresh market.

More and more instrumental investigations have been realized to improve evaluation of fruit and vegetable quality by introducing other quality characteristics in addition to sensory ones. The application of NIR spectroscopy to the assessment of the quality of fruits and vegetables, with reference to the determination of postharvest changes in proteins, lipids, carbohydrates, organic acids, ethanol, and chlorophyll in fruits and vegetables, has been studied.

A potential application of the results of flavor chemistry, new developments in descriptive analysis, consumer acceptance testing, and the interrelations of chemistry/sensory analysis, may be the trends in quality determination.

2. Quality Indices of Fruits

Fruits are commonly classified as pomaceous fruits, stone fruits, berries, tropical and subtropical fruits, hard-shelled dry fruits, and wild fruits. Quality in fruits, as in other products, is that combination of characteristics which makes them desirable to the buyer or user. Fruits are ordinarily chosen by appearance, because other methods for determination of quality are rarely available to the casual purchaser. Thus, to the vendor of fruits, whether at the field, the wholesale display, or in the retail store, such factors as size, shape, color, and freedom from external defects, are of compelling importance.

Unfortunately, the eating quality of many fruits cannot be accurately determined by the visible characteristics mentioned above. Those cultivars that have the most appealing contours, the reddest color, or the shiniest surface may be a disappointment at the table. Consumers are generally becoming more quality conscious, with the result that, from grower to retailer, the search is on for more than surface quality, and for standards that identify more than glamour characteristics.

To arrive at such standards, methods must be available to measure such real quality factors in fruit as flavor, texture, and freedom from internal defects. Because these qualities are affected by environment during growth, maturity at harvest, and holding conditions after harvest, measurements are needed for evaluation of quality in the field, proper time of harvest, and maintenance or deterioration of quality after harvest. Much effort has been devoted to these ends by scientists involved in fruit quality research and by those responsible for fruit standardization and inspection (see *Quality Control of Raw Materials*).

2.1. Sensory Attributes of Fruit

2.1.1. Appearance and Color of Fruit

Present emphasis is on the matter of eye appeal. Unless a commodity has eye appeal it is difficult to market, even though flavor and nutritional characteristics of the product or variety may be quite superior.

This is not intended to condemn the desire to have attractive fruit products. Attractive fruit appeals to the ordinary consumer and is apt to be enjoyed more than unattractive fruit; consequently, we need to take into consideration the characteristics that give eye appeal to the fruit.

Generally, small fruit will sell at a discount. Under glutted market conditions, small fruit may not even be considered salable. Larger fruit will command a great deal more of the market. It is, of course, possible to produce fruits that are too large for the usual commercial outlets.

Size, then, is another factor that affects market acceptance of the fruit that is produced. Standard sizes have become rather generally adopted, and fruit not within those limits usually has to be marketed as culls or for processing into some by-product other than a fresh product.

An important factor in eye appeal is good color. Present market trends have favored red fruit over yellow fruit. This has been true in apples, peaches, and many of the other fruits where both red and yellow fruits are produced. It is not only the amount, but also the quality of red that will have much more eye appeal and consumer acceptance than will one with the same amount with a dull, dark color.

Ground color refers to the green or yellow color of the fruit. Ground color is the other factor that affects the overall appearance of the fruit. A fruit may have a yellow ground color or a greenish ground color. Yellow and red are a much more attractive combination than red and green, and consequently, fruit with a good yellow ground color will be the most attractive.

This is especially true of the red that happens to be dull and dark red. Thus, one important characteristic, especially from the marketing point of view, is the color of the product.

External amount and intensity of surface color on a fruit of any type or cultivar is of prime importance to its appeal in the marketplace. Whether it is the deep red of one of the newer strains of apple, the bright orange of a Washington Navel orange, or the purplish black of a ripe fig, color is the one characteristic that makes fruits distinctive and attracts the buyer's eye.

Color is such an important aspect of fruit quality that grade standards almost universally specify the amount and shade of characteristic color required to meet a designated grade.

The amount of a required color in a fruit or vegetable is commonly estimated by inspectors, and this can be accomplished fairly accurately by eye. However, exact hues or intensities of color are difficult to describe, and the estimation of the human eye is often inaccurate.

Assistance to the human eye is available though color charts, containing either a wide range of colors or a selected range with specific application to certain fruit. Several charts have been developed for judging the ground color of apples and pears. They have been widely used by horticulturists and inspectors, as have other charts developed specifically for peaches, plums, and avocados.

Accuracy of color estimation beyond that attainable by the human eye is available through the use of instruments that measure the amount and quality of light reflected from a fruit surface. Reflectance curves made with a recording spectrophotometer have been used as a basis for color changes during maturation and ripening.

Photoelectric color-sorting machines are now available through commercial sources. These will separate fruits into several classes, from green to yellow (lemons), green to orange (oranges), or to several shades or amounts of red (apples). Sorting is accomplished by measurement of the light reflected from the product, the separation mechanism being activated by the quantity and quality of light received. The unit is used commercially for color-sorting lemons for the fresh fruit market, and red tart cherries for processing. It has been used experimentally for sorting freshly harvested oranges into classes based on the need for de-greening.

The determination of internal color in an intact fruit enables periodic measurement of chlorophyll as related to its decrease during ripening, or changes in internal plant pigments such as carotenes or anthocyanins.

These are useful measurements for the post-harvest physiologist who needs to know what changes are occurring without cutting the product to view the interior.

With a suitable light source, some light can be transmitted through a seemingly opaque fruit. With available light-gathering and measuring instruments, the extremely low light levels transmitted by intact fruits can provide meaningful data on internal color.

2.1.2. Texture of Fruit

Texture is an important component of fruit quality. A mealy apple, a grainy pear, or a ricey orange is less desirable to most consumers than one that lacks typical color. Flavor may be affected by texture because release of taste compounds in the mouth is related to tissue structure.

Texture is related to those attributes of quality associated with the sense of feel, as experienced by the fingers, the hand, or in the mouth. Included in texture are such sensations as hardness, softness, crispness, meatiness, juiciness, and toughness.

Among instruments developed for evaluating texture of fruits are pressure testers, penetrometers, compression testers, shear devices, and tensile testers. The measurement used depends primarily on the commodity being tested and on the particular aspect of texture important to the commodity.

2.1.3. Flavor of Fruit

Fruit flavor is difficult to determine by chemical means, primarily because a complex group of volatile compounds is combined in most to provide the typical flavor. Often the same compounds are present in genetically unrelated fruits, with the proportion of each, or the presence or absence of a few, resulting in vastly different flavors. Techniques in gas chromatography have permitted precise identification of the volatiles contributing to flavor in fruits.

Many of the volatiles contributing to strawberry, grape, pear, and citrus fruit flavors are known, but the combinations that produce the unique flavor of one type or cultivar of fruit as compared with another are as yet little understood (see *Food Quality and Assurance*).

Chemical methods are also available for detecting physical flaws or injuries to certain fruits. These include immersion in a solution of Methylene Blue dye for open lenticels or minute skin breaks in apples, and soaking in a dilute solution of 2,3,5-triphenyl*2H-tetrazolium chloride for peel injury in oranges.

Fruit	Dry matter	Total sugar	Titratable acidity[a]	Insoluble matter	Pectin[b]	Ash	PH
Apple	16.0	11.1	0.6 (M)	2.1	0.6	0.3	3.3
Pear	17.5	9.8	0.2 (M)	3.1	0.5	0.4	3.9
Apricot	12.6	6.1	1.6 (M)	1.6	1.0	0.6	3.7
Sour cherry	14.7	9.4	0.7 (M)	1.6	0.3	0.6	3.4
Sweet cherry	18.7	12.4	0.7 (M)	2.0	0.3	0.5	4.0
Peach	12.9	8.5	0.6 (M)	n.d.	n.d.	0.5	3.7
Plum/prune	14.0	7.8	1.5 (C)	1.3	0.9	0.5	3.3
Blackberry	19.1	5.0	0.6 (C)	9.2	0.7	0.5	3.4
Strawberry	10.2	5.7	0.9 (C)	2.4	0.5	0.5	n.d.
Currant, red	16.4	5.1	2.3 (C)	5.9	0.7	0.6	3.0
Currant, black	19.7	6.3	3.2 (C)	5.9	1.1	0.6	3.3
Raspberry	13.9	4.5	1.8 (C)	5.1	0.4	0.5	3.4
Grapes	17.3	14.8	0.4 (T)	n.d.	n.d.	0.5	3.3
Orange	13.0	7.0	0.8 (C)	n.d.	n.d.	0.4	3.3
Grapefruit	11.4	6.7	1.3 (C)	n.d.	n.d.	0.5	3.3
Lemon	11.7	2.2	6.0 (C)	n.d.	n.d.	0.4	2.5
Pineapple	15.4	12.3	1.1 (C)	1.5	n.d.	0.5	3.4
Banana	26.4	18.0	0.4 (M)	4.6	0.9	0.8	4.7
Cherimoya	19.0	13.0	0.2	n.d.	n.d.	0.9	n.d.
Date	90.0	61.0	n.d.	n.d.	n.d.	1.8	n.d.
Fig	22.0	16.0	0.4 (C)	n.d.	0.6	n.d.	n.d.
Guava	22.0	4.9	n.d.	n.d.	0.7	n.d.	n.d.
Mango	19.0	14.0	0.5	n.d.	0.5	n.d.	n.d.
Papaya	11.0	9.0	0.1	n.d.	0.6	n.d.	n.d.

[a] Calculated as malic (M), citric (C), or tartaric acid (T)
[b] Results are expressed as calcium pectate

Table 1. Average chemical composition of fruit as per cent of fresh edible portion

2.2. Chemical Composition of Fruit

Fruit composition can be strongly influenced by the variety and ripeness, thus data given should be used only as a guide. Table 1 shows that the dry matter content of fruits (berries and apples, stone, citrus, and tropical fruits) varies in the range of 10% to 20%. The major constituents are sugar, polysaccharides, and organic acids, while N-compounds and lipids are present in lesser amounts. Minor constituents include pigments and aroma substances of importance to sensory quality, and vitamins and minerals of nutritional importance. Nuts are highly variable in composition. Their moisture content is below 10%, N-compounds are about 20%, and lipids are as high as 50%.

2.2.1. N-Containing Compounds in Fruit

Fruits contain 0.1% to 1.5% N-compounds, of which 35% to 75% is protein (mainly enzyme proteins). Free amino acids are also widely distributed. Other nitrogen compounds are only minor constituents. The special value of nuts, with their high protein content, is generally well known.Protein and enzyme patterns, which can be obtained, for example, by electrophoretic separation, are generally highly specific for fruits, and can be utilized for analytical differentiation of species and variety. A number of aliphatic and aromatic amines are found in various fruits. They are formed in part by amino acid decarboxylation, such as in apples, or by amination or transamination of aldehydes. Some amines are derived from tyramine (e.g., hordenine, synephrine, octopamine, dopamine, and noradrenaline).

2.2.2. Carbohydrates in Fruit

Monosaccharides. In addition to glucose and fructose, the ratios of which vary greatly in various fruit, other monosaccharides occur only in trace amounts. For example, arabinose and xylose have been found in several fruits. An exceptional case is avocado, in which a number of higher sugars are present at from 0.2% to 5.0% of the fresh weight (D-manno-heptulose, D-talo-heptulose, D-glycero-D-galacto-heptose, D-glycero-D-manno-octulose, D-glycero-L-galacto-octulose, D-erythro-L-gluco-nonulose, and D-erythro-L galactononulose). Small amounts of heptuloses have been found in the flesh of apples, peaches, and strawberries, and in the peel of grapefruit, peaches, and grapes.

Oligosaccharides Saccharose (sucrose) is the dominant oligosaccharide. Other disaccharides do not have quantitative importance. Maltose occurs in small amounts in grapes, bananas, and guava (Myrtaceae). Melibiose, raffinose, and stachyose have also been detected in grapes. In ripe bananas, 6-Kestose has been identified. The study of monosaccharide and oligosaccharide composition may be useful in detection of adulteration of fruit juices, for example.

Other oligosaccharides occur only in trace amounts. The proportion of reducing sugars to sucrose can vary greatly (Table 2). Some fruit have no saccharose (e.g., cherries, grapes, and figs), while in some the saccharose content is significantly higher than the reducing sugar content (e.g., apricots, peaches, and pineapples). Among sugar derivatives, D-sorbitol is abundant in Rosaceae fruits (pomme fruits, stone fruits). For example, its concentration is 300 mg/100 ml to 800 mg/100 ml in apple juice. Because fruits such as berries, citrus fruits, pineapples, or bananas do not contain sorbitol, its detection is of analytical importance in the evaluation of wine and other fruit products. Meso-inositol also occurs in fruit; in orange juice it ranges from 130 mg/100 ml to 170 mg/100 ml.

Fruit	Glucose	Fructose	Saccharose
Apple	1.8	5.0	2.4
Pear	2.2	6.0	1.1
Apricot	1.9	0.4	4.4
Cherry	5.5	6.1	0.0
Peach	1.5	0.9	6.7
Plum/prune	3.5	1.3	1.5
Blackberry	3.2	2.9	0.2
Strawberry	2.6	2.3	1.3
Currant, red	2.3	1.0	0.2
Currant, black	2.4	3.7	0.6
Raspberry	2.3	2.4	1.0
Grapes	8.2	8.0	0.0
Orange	2.4	2.4	4.7
Grapefruit	2.0	1.2	2.1
Lemon	0.5	0.9	0.2
Pineapple	2.3	1.4	7.9
Banana	5.8	3.8	6.6
Date	32.0	23.7	8.2
Fig	5.5	4.0	0.0

Table 2. Sugar content in various fruit as per cent of the edible portion (from Belitz and Grosch, 1982)

Polysaccharides. All fruit contain cellulose, hemicellulose, pentosans, and pectins. The building blocks of these polysaccharides are glucose, galactose, mannose, arabinose, xylose, rhamnose, fructose, and galacturonic and glucuronic acid. The pectin fractions of fruits are particularly affected by ripening, with a decrease in the insoluble pectin fraction. The total pectin content can also decrease. Starch is present primarily in unripe fruits, and its content decreases to a negligible level as ripening proceeds. Exceptions are bananas, in which the starch content can be 3% or more even in ripe bananas, and in various nuts such as cashews and Brazil nuts.

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Biographical Sketch

Dr. Pál J. Molnár is Scientific Advisor and Director of the Food Quality Center at the Central Food Research Institute in Budapest. He studied Food Technology and Biochemistry at Humboldt University of Berlin, 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). Dr. Molnár has published three scientific books and more than 300 papers in Hungarian and international periodicals. In addition, he has edited more than ten conference proceedings in the field of quality development. He has been awarded several Hungarian and German recognitions.