Determinants of eating quality in fruit and vegetables

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Summary

Eating quality of fruit and vegetables is determined by many factors. Each product has a different balance of attributes that make it unique. Attributes such as sweetness (sugar), sourness (acidity), sugar/acid ratio, bitterness, astringency, aroma and colour are the main determinants. Other factors such as vitamins, minerals, dietary fibre and protective agents arising from flavonoids, phytosteroids and other secondary plant products are also important. In addition, fruit and vegetables must be safe to eat.

Using suitable post-harvest handling technologies in the supply chain can extend the shelf life of fruit and vegetables and maintain eating quality. Incorporation of proper quality assurance systems in the production and distribution processes will be able to further ensure quality and safety for human consumption.

Quality

Many people have favourite definitions for quality. In production, it is not simply a degree of excellence, peculiar character, or distinguishing attribute, as defined in dictionaries. Quality as a goal should be formulated from the perspective of the consumer. The same product will have different quality from the perspective of seller or buyer. Experts have defined quality briefly: "conformance to requirements", "fitness for purposes", "the sum of the attributes or properties that describe the product", "conformance to a customer's price-limited anticipated needs", and other analogous definitions. A common definition was formulated by the International Organisation for Standardisation (ISO) in Europe: "Quality in the degree in which the whole or characteristics of a product meets the requirements that spring from the goal of use".

Eating quality

Eating quality of a product is conventionally said to be made up of a composite of attributes, whose relative importance varies with the product. More correctly, each product has a different balance of these attributes, which make it unique. Apples, nashi and carrots are crisp; melons and grapes are sweet. Conventionally, flavour (which can be defined as being made up of taste and aroma) and texture are taken as the main components of eating quality. The other components are nutritive value, safety and appearance.

To the nutritionists there are several factors that may affect the eating quality.

(1) What makes fruit and vegetables attractive to eat? Factors such as taste, aroma, texture, sugar/acid balance, flavour volatiles (alcohols and esters) and crispness are the main determinants.

(2) What makes fruit and vegetables desirable in the diet? Traditional virtues are generally low fat content, or if fats are abundant they are 'good' ones (eg avocado). Often fruit and vegetables will be a good source of vitamins, minerals and dietary fibre (pectins).
(3) Food must be safe to eat. Fruit and vegetables have until recently been considered of negligible risk, but now it must be said they present some (low) risk if not handled properly.
(4) Protective effects (eg antioxidants) of fruit and vegetables, arising from flavonoids, phytosteroids and others.

Components of flavour in fruit and vegetables

Flavour is made up of sweetness, sourness (acidity), astringency, bitterness and aroma. Flavour is associated most closely with sensory evaluation. Stone *et al.* (1) recommended that sensory analysis should "begin with the consumer rather than with a preconceived notion as to what is best for consumer".

Flavour can be produced by a single compound or a group of compounds both natural and artificial. The main components of flavour and texture in fruit and vegetables are sugars, acids and aroma volatiles such as phenolic compounds.

Sweetness

The maturation of fruit and vegetables is often accompanied by profound changes in their chemical composition. The most prominent one is the conversion of carbohydrate/starch into sugar. Therefore the immature apple tastes starchy and a mature one tastes sweet. Ideal sugar content can also reduce the effect of acidity and produce excellent eating quality.

Sugar content – determined by chemical analysis procedures for total and reducing sugars.

Total soluble solids (TSS) content – measured using refractometers or hydrometers; can be an indicator of sweetness because sugars are a major component of soluble solids.

Sourness (acidity)

This is the amount of acids present in fruit and vegetables. Acidity can be determined by measuring pH of extracted juice with either a pH meter or pH indicator paper. It can also be determined by measuring total titratable acidity.

For some fruits, such as citrus, melons, kiwifruit, papaya and pomegranates, sugar/acid ratio is important in determining eating quality.

Astringency

Astringency can be determined by taste testing or by measuring tannin content.

Bitterness

Bitterness can be determined by taste testing or by measuring alkaloids or glucosides that cause the bitter taste.

Aroma

Aroma can be determined by sensory panels in combination with identification of volatile compounds responsible for specific aroma of a fruit or vegetable.

Phenolic compounds and sweetness

Sugar is one the main contributers to sweetness and hence eating quality in fruit and vegetables. Some sugars are sweeter than the other (2). For example, fructose is sweeter than glucose and sucrose (Table 1). Fruit that has high fructose content will taste sweeter than other fruit that have the same amount of sucrose or glucose.

Table 1. Comparison of relative sweetness of several compounds

Compound	Degree of sweetness (relative to sucrose)
Sucrose	1.0
Glucose	0.7
Fructose	1.3
Cyclamate	30.0
Saccharine	500.0
Naringenine dihydrochalcone	500.0
Neohesperidine dihydrochalcone	1000.0

Several artificial sugars have been used to enhance sweetness, because artificial sugars have low calories. Some are being used as sugar substitutes for people with diabetes. In the past, cyclamate and saccharine have been used widely because of their high degree of sweetness (Table 1). However, the use of cyclamate and saccharine are restricted or banned because it is believed that they could be carcinogenic.

The eating quality of some citrus can be very high if consumed with the skin, for example a small size citrue called kumquat. Some citrus skin contains natural phenolic compounds, such as naringenine dihydrochalcone and neohesperidine dihydrochalcone, that are much sweeter than sucrose (Table 1). Research is in progress with the aim to commercialise these sweet phenolic compounds.

Chemical compounds/components and characteristic flavour in fruit and vegetables

Characteristic flavours in fruit and vegetables are caused by some specific chemical compounds. Some examples of the identified compounds are shown in Table 2. The characteristic flavour in apple is caused by ethyl-2-methylbutyrate, in banana by a combination of amyl acetate, amyl-propionate and eugenol, and in lemon by citral.

Components of texture in fruit and vegetables

The main textural attribute in fruit and vegetables is firmness, which is commonly measured by puncture and deformation tests, eg by using Effegi penetrometer and Magness-Taylor Pressure Tester. Other techniques based on acoustic (3) or on impact response (4) have been used to quantify fruit physical firmness non-destructively. However, it has not been demonstrated that these new techniques reflect human perceptions of firmness.

Other textural attributes include succulence and juiciness. They are measurements of water content (an indicator of succulence and turgidity) and extractable juice (an indicator of juiciness).

Table 2. Some chemical compounds that produced characteristic flavour in fruit and vegetables

Examples	Chemical compounds
Apple	Ethyl-2-methylbutarate
Banana	Amyl acetate, amyl-propionate and eugenol
Coconut	α-Nonalactone
Lemon	Citral
Mandarin	Methyl-n-methylantranilate and tymol
White onion	Di-2-Prophenylsulphide
Ginger	Gingerol
Onion	Dipropyl disulphide, propanatyol
Mushroom	Lentionine

Colour and shape of fruit and vegetables

Although colour and shape do not contribute physiologically to flavour and texture, they have some psychophysical effects, cooks call it 'eye appeal' of food. If food looks good, it may taste better. Fruit and vegetables must have their typical acceptable shape, eg angularity of banana and full cheeks of mangoes. The external colour of fruit and vegetables is only the outward manifestation of complex internal biochemical reactions. Apple may be red and broccoli is green. If a banana does not look golden yellow enough, it may not taste good to someone although it has right sugar level and firm texture.

Maturity indices for optimum eating quality in fruit

Sweetness (TSS), firmness and colour are often used to determine maturity indices for optimum eating quality in fruit. In order to ensure good eating quality, fruit must achieve certain maturity indices before they can be harvested commercially. Table 3 shows some examples of the maturity indices used to harvest plum for export markets (5).

With plums, skin colour is usually a reliable guide for harvest maturity and is closely associated with taste and appearance after storage and ripening. Sugar content (TSS) and firmness are less reliable guides of harvest maturity and quality. However, both of these indices do change during fruit maturation as fruit gets sweeter and softer. Therefore sugar content and firmness should be taken into account along with skin colour in determining harvest maturity in plums to ensure good eating quality. Taste panels preferred plums with higher maturity (5).

Quality and food safety

'Fresh Fruits and Vegetables: Quality and Food Safety Symposium' was conducted in May 1998 at the US Department of Agriculture, Agricultural Research Centre in Beltsville, MD, USA. The theme of the Symposium was especially timely because of the importance of the research into quality and food safety due to the increased consumption of fresh fruit and vegetables and the shifting emphasis in marketing of fresh produce towards a more convenient, fresh-cut form requiring less preparation time.

Table 3. Harvest maturity indices for optimum eating quality for four export plum varieties

Variety	Year	TSS (%)	Firmness (kg)	Colour[1]
Santa Rosa	1987	12.4	3.5	6.0
	1988	11.6	6.0	5.3
	1989	12.5	5.3	4.0
Laroda	1987	13.1	5.2	4.5
	1988	13.9	5.2	4.5
	1989	15.8	5.9	5.0
Stirling	1987	14.9	3.2	5.5
	1988	14.9	4.3	4.7
	1989	15.9	4.3	6.0
Ruby Blood	1987	15.8	5.5	4.5
	1988	15.8	4.6	4.1
	1989	13.8	5.1	4.5

[1] Skin colour values refer to colour chart numbers. Generally, increasing value represents changes in ground colour from green to yellow and increase in area and/or intensity of red skin colour.

Consumers are demanding fresh fruit and vegetables of high eating quality, including good appearance and colour, flavour, texture and free from pesticides and harmful pathogens.

Fruit and vegetables are relatively low risk from a food safety viewpoint, but they are definitely not free from risk. Most documented cases of fruit and vegetable-borne illness have been traced to faecal contamination. For example, fresh and inadequately composted manure is sometimes used. *E. coli O157:H7* has been shown to survive up to 70 days in bovine faeces (6).

An increasing, although still limited, number of reported food-borne illnesses have been traced to fresh produce. A series of outbreaks recently investigated by the Centre for Disease Control and Prevention (CDC) has linked a variety of pathogens to fresh fruit and vegetables harvested in the United States, Central America and elsewhere (Table 4) (7). Various possible points of contamination have been identified during these investigations, including contamination during production and harvest, initial processing and packing, distribution and final processing (Table 5).

Table 4. Food-borne outbreaks traced to fresh produce 1990-1996 in North and Central America (7)

Year	Pathogen	Produce	Cases (No.)
1990	*Salmonella* Chester	Cantaloupe	245
1990	*S.* Javiana	Tomatoes	174
1990	Hepatitis A	Strawberries	18
1991	*S.* Poona	Cantaloupe	>400
1993	*E. coli* O157:H7	Apple cider	23
1993	*S.* Montevideo	Tomatoes	84
1995	*S.* Stanley	Alfalfa sprouts	242
1995	*S.* Hartford	Orange juice	63
1995	*E. coli* O157:H7	Leaf lettuce	70
1996	*E. coli* O157:H7	Leaf lettuce	49
1996	Cyclospora	Raspberries	978
1996	*E. coli* O157:H7	Apple juice	71

Table 5. Events and potential contamination sources during fruit and vegetables processing

Event	Contamination sources
Production and harvest	
growing, picking,	irrigation water, manure,
bundling	lack of field sanitation
Initial processing	
washing, waxing	wash water, handling
sorting, boxing	
Distribution	
trucking	ice, dirty trucks
Final processing	
slicing, squeezing	wash water, handling
shredding, peeling	cross-contamination

Recently consumer preferences have moved toward greater convenience, by having fresh fruit and vegetables prepared in a fresh cut form. Cutting produce before marketing removes natural barriers, exposing cut surfaces to contaminants and pathogens. Researchers must develop new protective strategies to ensure that pathogens do not grow on the produce.

In order to prevent disease outbreaks and to improve the safety of fruit and vegetables for human consumption, some kind of quality assurance system has to be incorporated into the growing and supply chains.

SQF quality system

Quality assurance is a management system for controlling quality through establishing operational procedures involving the integration of the processes, services and people concerned with the product. The critical control points for quality are identified throughout the pre-harvest (irrigation, fertilisation, pesticide application and other cultural practices) and post-harvest chain and procedures put in place to monitor and eliminate hazards. The end result is that quality and safety are built into the system.

SQF Quality System was developed by Agriculture Western Australia. SQF is the acronym of Safe Quality Food. The SQF system is a Hazard Analysis and Critical Control Points (HACCP) quality assurance system designed specifically for all food businesses. Based on world food standards, SQF provides the tools for any food business to demonstrate compliance with food safety standards and customer quality requirements. The SQF systems uses the HACCP method and is compatible with ISO 9000 standards allowing a business to build their system to achieve certification to the ISO 9000 standards if required. SQF accredited fruit and vegetables will be safe to eat and have good quality.

Post-harvest handling and eating quality in fruit and vegetables

Respiration and transpiration are the most important post-harvest processes that affect storage life and eating quality of fruit and vegetables. Respiration is the process by which the stored food, especially carbohydrates with the fruit and vegetables, is utilised to provide energy for maintaining life. Transpiration is the process of loss of water in vapour form from the fruit and vegetable tissues. Post-harvest life can be prolonged, and eating quality maintained, by reducing the rate of respiration and transpiration. Low temperature storage in a high relative humidity environment will greatly prolong shelf life and maintain eating quality. Table 6 shows the effects of temperature and relative humidity on the shelf life of cauliflower (8).

Table 6. Effects of temperature and relative humidity on shelf life of cauliflowers

Temperature (°C)	Relative humidity (%)	Shelf life (days)
0	90-95	21
4	80-90	14
20	60-70	3

A good quality cauliflower should have the following minimum requirements.

- Cauliflower should be intact, firm, clean, sound and fresh, free of any foreign matter and pests and not affected by disease.
- There should be no off-smell.
- The curd should have no discolouration.
- Curds in the same carton must have uniform size and weight.

Chemical changes in Haden, Irwin, Kent and Keitt mangoes stored at 16-28°C and 85-90% relative humidity were followed to determine the optimum storage and ripening conditions (9). The results showed β-carotenoids (vitamin A) were higher at 22-28°C than 16-20°C, whereas ascorbic acid (vitamin C) was higher at the lower temperatures. The vitamin C content in the post-harvest treatment and storage of papaya fruit was studied by Tan *et al.* (10). Hot water treatment extended the shelf life of papaya but did not affect the vitamin C content after 7 days storage at room temperature.

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