ABSTRACT

Observation of consumer expectations regarding food quality provides the basic for any successful food production and marketing. This is also true for fresh fruits and vegetables which are increasingly valued as an important part of the diet. Traditional quality evaluation of fruits and vegetables is associated, primarily, with appearance attributes, such as size, shape, surface color and defects; tactile characteristics, such as firmness or hardness; and internal quality attributes, such as sugar and/or oil content, vitamins and internal defects and disorders. However, sensory attributes play an important role in a consumer’s decision to purchase fresh or fresh-cut fruit or vegetables. Preharvest practices such as cultivation, growing system, soil type, and fertigation, as well as harvest practices, such as choice of the stage of maturity and postharvest treatments, such as controlled or modified atmosphere packaging, coating, and physical or physicochemical treatments may affect the sensory and flavor attributes of fresh and fresh-cut product. The goal of this mini review is to summarize the information that has been published during the last 4 years on preharvest practices and postharvest treatments that affect the sensory characteristics of fruits and vegetables, marketed as fresh, or fresh-cut products.

Keywords: CA, fruit, MAP, shelf life, storage, vegetable

Abbreviations: 1-MCP, 1-methylcyclopropene; AVG, aminoethoxyvinylglycine; CA, controlled atmosphere; ETH, ethephon; LDPE, low density polyethylene; MAP, modified atmosphere packaging; PE, polyethylene; PET, polyethylene terephthalate

INTRODUCTION

Over the last half-century there have been many changes in the way fruits, vegetables and ornamentals are grown, stored and distributed. In a society where, increasingly, food is being seen as a source nutraceuticals, the nutritional value of fresh produce is coming under increasing scrutiny. Community concerns about the effects of poor diets on health are being reflected in campaigns to increase the consumption of fresh fruits and vegetables, and also of fresh-cut products. One of the key factors in achieving this is to provide fresh or fresh-cut produce of high quality and safety standards. Product quality is a complex issue, since it includes visual characteristics, physical properties such as texture, mineral and vitamin contents, and flavour and other organoleptic characteristics (Shewfelt 1999). Once produce is harvested, postharvest handling practices do not improve organoleptic characteristics (Shewfelt 1999). Once produce is harvested, postharvest handling practices do not improve organoleptic characteristics (Shewfelt 1999). Once produce is harvested, postharvest handling practices do not improve organoleptic characteristics (Shewfelt 1999). Once produce is harvested, postharvest handling practices do not improve organoleptic characteristics (Shewfelt 1999). However, sensory quality is important for consumer satisfaction and influences further consumption. The key to increasing consumer consumption of fresh fruits and vegetables and fresh-cut products, without loss of grower income, lies in providing produce of superior flavour, which it retains during prolonged storage and extended shelf life.

Preharvest practices such as cultivation, growing systems, soil type or fertigation; harvest practices, such as choice of right stage of maturity; and postharvest treatments,
such as grading, packing, controlled or modified atmosphere packaging, coating, and physical or physicochemical treatments may affect the flavour and other sensory attributes of fresh and fresh-cut products. The goal of this mini-review is to present examples of several aspects that have been addressed in papers published during the last 4 years, regarding preharvest practices and postharvest treatments that help to determine the sensory characteristics of fruits and vegetables marketed as fresh or fresh-cut products.

PREHARVEST PRACTICES

Achievement of the best potential postharvest quality and shelf-life of fresh fruits and vegetables depends on the conditions and events before harvest: everything from the cultivar to soil type and fertigation practices, as well as weather conditions and pest control programs, affect the quality of harvested produce and its sensory properties.

Virtually all postharvest quality factors are genetically controlled and can differ among varieties, therefore, from a quality standpoint, cultivar selection may be an important management decision in crop production (Hampson and McKenzie 2006). Sinesio et al. (2007) found that for most sensory characteristics of tomatoes grown in open fields, the greatest variation was caused by differences in genotypes, suggesting that there was considerable degree of genetic diversity. Minor effects were attributed to year of harvest and differences between experimental fields. A new mandarin cultivar currently designated as selection LB8-9 has been evaluated by a fruit taste panel for consumer, acceptability in comparison with ‘Sunburst’ and ‘Minneola’ mandarins, and it achieved a better acceptance score than ‘Minneola’ after 50 d of storage at 4°C. Overall, LB8-9 has good potential as a new fresh fruit for the consumer, and no serious problems were noted under typical postharvest handling (Dou and Gmitter 2007). The overall eating quality of blueberry fruit depended on the cultivar, it was best correlated with flavour scores followed by sensory scores for intensity of juiciness, bursting energy, sweetness, and acceptability of appearance (Saffner et al. 2008). Apple (Malus domestica Borkh.) cultivars differ in their aroma and composition of volatile acetates in their fruit flesh and peel. Cv. ‘Fuji’ flesh contains substantial levels of 2-methyl butyl acetate (fruity banana-like odour), while the flesh of cv. ‘ Granny Smith’ apples lacks this compound. Granny Smith apples accumulate mainly hexyl acetate (apple-pear odour) in their peel. Feeding experiments indicated that ‘Fuji’ apples were able to convert hexanol and 2-methyl butanol to their respective acetate derivatives in vivo, while ‘Granny Smith’ apples could only convert exogenous hexanol to hexyl acetate (Holland et al. 2005).

Soil type was found to affect sensory attributes of freshly harvested produce. Clay soil appeared to have some advantages over sandy loam soil in producing cantaloupe fresh-cut produce. Clay soil appeared to have some advantages over sandy loam soil in producing cantaloupe fresh-cut produce. Clay soil appeared to have some advantages over sandy loam soil in producing cantaloupe fresh-cut produce. Clay soil appeared to have some advantages over sandy loam soil in producing cantaloupe fresh-cut produce. Clay soil appeared to have some advantages over sandy loam soil in producing cantaloupe fresh-cut produce. Clay soil appeared to have some advantages over sandy loam soil in producing cantaloupe fresh-cut produce. Clay soil appeared to have some advantages over sandy loam soil in producing cantaloupe fresh-cut produce. Clay soil appeared to have some advantages over sandy loam soil in producing cantaloupe fresh-cut produce.

After harvest, quality cannot be improved, only maintained; therefore it is important to harvest fruits, vegetables, and flowers at the proper stage and size and at peak quality. Immature or over-mature produce may not last as long in storage as that picked at proper maturity.

Harvesting papaya fruit at different stages of maturity altered their postharvest physiology, and early harvesting reduced fruit quality but did not make it unacceptable for consumption (Bron and Jacomino 2006). On the other hand, Kreck et al. (2005) found general acceptance of fresh overripe plum (Prunus domestica L.) picked at the end of the harvesting period; although statistical correlations between analytical and sensorial parameters were mainly found between sweetness and soluble dry mass and between the attributes sourness and firmness; sweetness and sourness were the deciding factors in determining the general acceptability of the fruits by consumers. Apple aroma volatiles and sensory quality were significantly affected by harvest date when it was based on the fruit colour; fruit of higher red colour grading had higher concentrations of aroma volatiles than those of lower grading (Thybo et al. 2005b). Muskelman melon varieties should be harvested when light green with some green areas, in order to obtain the best quality, aroma and other sensory attributes, and also longer shelf. The main flavour components detected were esters which increased 1.0-15-fold from unripe to ripe and overripe stages (Senesi et al. 2005).

Fresh-cut melon quality can also be affected by the stage of maturity at harvest. Fresh-cut chunks of orange-fleshed honeydew (‘Honey Gold’, ‘Orange Dew’, ‘Temptation’ and three breeding lines), a green-fleshed honeydew (‘Honey Brew’) and an orange-fleshed cantaloupe (‘Crui-
CO2) retained color and maintained excellent eating qualities during long-term storage (Sivakumar and Korsten 2006b). Treating cv. ‘Packham’s Triumph’ pears. After 2 months of storage, pears treated with 1-MCP or CA-stored fruit recovered their capacity for ripening physiology of ‘Ananasnaya’ hardy kiwifruit and indicate that both coated and uncoated fruit were well liked. These results provide important information regarding the ripening physiology of Actinidia arguta [Siebold & Zucc.] Planch. Ex Miq) fruit were evaluated according to hedonic scale by a consumer sensory panel (Fisk et al. 2008), and the consumer test indicated that both coated and uncoated fruit were well liked. This alternative method of slowing ripening of fruits or vegetables after harvest is by exposing them to 1-methylcyclopropene (1-MCP), which inhibits ethylene action (Blankenship and Dole 2003). 1-MCP (625 nL/L) and CA-stored (CA; 2.0-2.5 kPa CO2, 1.8-2.0 kPa O2) ‘Royal Gala’ apples were preferred by consumers in all trials, indicating that both treatments can maintain the preferred textural characteristics of the fruit, especially during long-term storage (Moya-Leon et al. 2007). Moya-Leon et al. (2006) also investigated the effects of long-term storage with 1-MCP under CA on aroma production and consumer acceptance of ‘Packham’s Triumph’ pears. After 2 months of storage, pears kept under regular cold storage developed the highest content of volatile compounds and also the highest odour value, and were preferred by sensory panelists, whereas CA storage and 1-MCP treatment reduced the production of aromatic volatiles by the fruit. Hexyl acetate with fruity notes was found to be the main contributor to the aroma of the pears, followed by butyl acetate and pentyl acetate, while alcohols showed a poor contribution. Nevertheless, after a longer storage period, pears treated with 1-MCP or stored under CA conditions recovered their capacity for volatiles production with odour activity, and the panelists preferred the 1-MCP-treated over the CA-stored fruit.

The effect of CA on sensory quality of vegetables was also tested (Renquist et al. 2005). Sensory assessment of green asparagus (Asparagus officinalis) indicated that spears held in CA for 6 days had similar flavour and acceptability to those held in air for 1 day.
Physicochemical treatments

Inhibition of physiological or/and pathological deterioration of fresh harvested produce by a combination of any types of physical, chemical or environment-friendly chemical methods is called ‘physicochemical’ treatment.

Hypobaric (low-pressure) storage offers considerable potential as a method to prevent postharvest loss of freshly harvested fruits and vegetables. Effects of hypobaric storage on the biological characteristics of green asparagus were compared with those refrigerated and room-temperature storage. Hypobaric storage clearly improved sensory quality and delayed the post-harvest senescence process of asparagus (Li et al. 2006). Litchi fruits which are highly susceptible to pericarp browning were peeled and stoned, and the arils were treated with anti-browning agents (cytoxane, ascorbic acid or 4-hexylresorcinol) along with osmo-vacuum dehydration (OVD) (sucrose syrup for 10 min at 570 mmHg vacuum followed by a relaxation of 10 min at atmospheric pressure) and stored at 4°C (Shan and Nath 2008). The combination of treatment with anti-browning agents and by osmo-vacuum dehydration was found to be most effective in preventing the changes in litchis, and the samples were acceptable up to 24 days, whereas the samples that received only OVD treatment were lost acceptable up to 10 days. The increased rate of titratable acidity and reduced dry matter content in the O3-treated fruit, which retained a good appearance and overall quality in the slices, but with reduced aroma. Ozone did not cause any damage or off-flavour in either sliced or whole tomatoes.

The overall quality of fresh harvested strawberries improved whereas in commercial treated fruit it was improved in terms of properties evaluated by a taste panel; this was attributed mainly to the increased rate of titratable acidity and reduced dry matter content (Khosroshahi et al. 2007).

The effects of postharvest irradiation with visible light and UV-B radiation on several sensory related properties were measured in ‘Aroma’ apples and the relationships between these properties were evaluated (Hagen et al. 2007). The results suggest that postharvest irradiation can be utilized to improve the health value and colour appearance of apples without changing important taste-related parameters. Combined treatments with hot air and UV-C illumination were applied to minimally processed broccoli (Brassica oleracea L.) florets to investigate their effects on several quality and senescence parameters (Lemoine et al. 2008). In general, the results suggest that the effect of heat was more important than that of UV-C in extending the postharvest life of broccoli florets. Treatment at 48°C combined with a UV-C dose of 8 kJ/m² yielded the highest retention of green colour and the best maintenance of organoleptic quality.

Electron beam irradiation did not affect the overall sensory quality of mangoes at doses up to 1.5 kGy. Only fruits irradiated at 3.1 kGy were unacceptable by the panelists. Irradiation at 3.1 kGy enhanced the fruit’s aroma characteristics (Moreno et al. 2007a). E-beam irradiation of blueberries up to 1.6kGy was found to be a feasible decontamination treatment that maintains the overall fruit quality attributes (Moreno et al. 2007b).

The efficacy of ethanol maintaining the overall quality of two table grape cultivars - 'Superior' and 'Thompson Seedless' - was tested (Lurie et al. 2007). The taste of the berries was not impaired by any of the ethanol applications. However, the taste of 'Thompson Seedless' grapes held for 8 weeks in modified atmosphere storage was affected by CO₂ levels above 7%. The effect of aqueous chlorine dioxide (ClO₂) treatment on grape quality was examined during storage (Kim et al. 2008). Sensory evaluation showed that the treated grapes had better sensory scores than the controls, and therefore, ClO₂ treatment could be useful in improving the quality of grapes during storage.

Fruits of winter guava (Psidium guajava) were harvested at horticultural maturity and were exposed to ethylene gas at 100 μL/L for 24 h, or to aqueous solutions of ethylene at concentrations of 500, 750 or 1000 μL/L (Mahajan et al. 2008). Treatment with ethylene gas or 1000 μL/L ethylene solution resulted in pleasant flavour, more desirable firmness and more acceptable sensory quality than the other treatments. The control fruits showed very poor ripening and were hard in texture with poor quality attributes.

Application of brief anaerobic stress might be beneficial for postharvest fruit quality and might induce volatile production and thereby improve fruit aroma (Pesis 2005). Shi et al (2005) subjected ‘Mucrott’ mandarins and ‘Star Ruby’ grapefruit to anaerobic stresses by exposing them to N₂ atmospheres. They found that mandarins held under N₂ exhibited higher and earlier increases in the accumulation of the off-flavour volatiles than grapefruit, and sensory evaluations indicated that the taste of mandarins deteriorated markedly following exposure to anaerobic conditions and was rated as unacceptable after 48 h under N₂ whereas the taste of grapefruit deteriorated only slightly and was rated acceptable even after 72 h of N₂ exposure (Shi et al. 2005). Fallik et al. (2005a) found that following 24 h of anoxia treatment, tomatoes that were held at 20°C for 12 days had organoleptic qualities similar to those of untreated fruit that were kept in cold storage followed by simulated marketing condition.

The rapid-ripening summer apple cultivar ‘Anna’ was treated with 1-MCP at harvest, and fruit quality was measured instrumentally at intervals during ripening at 20°C, and the instrumental rating were compared with the sensory ratings of a trained panel and the hedonic scores of untrained tasters (Pre-Aymard et al. 2005). The highest hedonic scores were obtained by apples treated with 1-MCP at 1 μL/L and ripened for 12 days at 20°C. Recently, Gal et al. (2008) reported that the overall aroma notes in commercially-treated ‘Galía’-type melons as tested by a trained panel, were significantly higher than those of 1-MCP-treated fruit. However, 1-MCP-treated fruit were preferred by both trained and untrained panels, which disliked commercially-washed and waxed fruit. Methyl acetate, as well as methyl 2-butylnonate, which are associated with ‘off-flavour’ and over ripening were significantly higher in 1-MCP-treated fruit. The grassy note due to hexanalin remained relatively high in 1-MCP-treated fruit after storage, while it was not detected in commercially-treated fruit. Ethanol, ethyl acetate and ethyl hexanoate volatiles that are associated with “off-flavour” and over ripening were significantly higher in commercially-treated fruit.

Today the postharvest practice of 5% calcium chloride solution increased bound Ca levels, maintained the firmness of fresh-cut melon (Cucumis melo var. saccharinus Naud) and resulted in better sensory quality than control treatments or CaCl₂ treatment at 5°C (Aguyro et al. 2008). Calcium propionate treatment decreased metabolic activity but imparted a slight off-flavour to the cut melon, therefore, treatment at lower calcium propionate concentrations must be studied to avoid this off-flavour. No Ca dip treatment induced a salty or bitter taste.
CONCLUDING REMARKS

The postharvest quality of fruits and vegetables can be influenced by a wide variety of genetic factors, preharvest and harvest practices, and postharvest treatments, as well as handling, transportation and marketing practices, but it is generally accepted that quality is established in the field (Rijcken and van Kooten 2006; Hodges and Toivonen 2008).

Consumption of fresh fruits is increasing as consumers become more aware of their nutritional value and their role in disease prevention. Improving the sensory properties of fresh fruit or vegetables that reach the consumer would add value, increase consumption, and create new markets for these commodities (Song and Forney 2008). Therefore, sensory quality is emerging as one of the most important quality attributes of horticultural products, and one that needs to be optimized through breeding, preharvest, harvest and postharvest practices. While sensory quality is recognised as an important factor in consumer acceptance and repeat purchase, it is seldom included in economic analyses of the fresh or the fresh-cut product market because of the difficulties in measuring it and matching it to consumer expectations (Laureati et al. 2006).

A better understanding of aroma and flavour metabolism, and its genetic control, improved breeding methods, and increased knowledge of maturation mechanisms and of the effects of pre- and postharvest practices will enable the consumer to purchase a better and tastier fresh or fresh-cut fruits and vegetables. Therefore, molecular genetic manipulation of specific genes or groups of genes to enhance or modify aroma and flavour generation in fruits and vegetables promises to be a highly active area of future research. In addition, training people to participate in taste panels will lead to potential product descriptors and to indicators of future product acceptance, though not to accurate purchase predictors. Furthermore, new instrument technologies such as Near Infra red (NIR) measurements or similar means can improve the capacity to predict the sensory quality of freshly harvested produce (Francois et al. 2008).

Nevertheless, in dealing with new cultivars, further work will be required to understand and optimise the commercial handling of each commodity, including selection of harvest maturity and optimisation of storage protocols.

ACKNOWLEDGEMENTS

Contribution from the Agricultural Research Organization, the Volcani Center, Bet Dagan, Israel, No 531/08.

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