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Towards a new definition of quality for fresh fruits and vegetables

Marios C. Kyriacou[a,*], Youssef Rouphael[b]

[a] Department of Vegetable Crops, Agricultural Research Institute, 1516 Nicosia, Cyprus
[b] Department of Agricultural Sciences, University of Naples Federico II, 80055 Portici, Italy

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ABSTRACT

The quality of fruits and vegetables constitutes a dynamic composite of their physicochemical properties and consumer perception. Attempts at defining quality often discriminate between intrinsic characteristics inherent to the nature of the products, dictated by genotypic, agroenvironmental and postharvest factors, and extrinsic characteristics influenced by socioeconomic and marketing factors which condition consumer perception of the products and formulate quality standards. The current regulatory context for fruit and vegetable quality comprises crop-specific class standards based on key visual and limited compositional criteria and lays primary emphasis on visual attributes at the expense of flavour, nutritional and functional attributes related to phytonutrient content. The potential quality of fresh fruits and vegetables in the horticultural supply chain is defined in the period preceding harvest, however the full development of quality characteristics can be optimized through the use of appropriate postharvest technology. The current review provides a discourse on the relative significance of the various factors configuring quality in fruits and vegetables, with emphasis on intrinsic factors pertaining to the preharvest period, and also on extrinsic factors shaping quality for supply chain stakeholders and consumers. Preharvest factors discussed include: 1) optimization of stage-specific production inputs, 2) biofortification through targeted plant nutrition, 3) application of accurate crop- and cultivar-specific harvest maturity indices, 4) optimized application of controlled stress conditions that increase primary and secondary metabolites and improve organoleptic and functional aspects of quality, and 5) redirection of horticultural breeding towards improving flavour in horticultural products.

1. Introduction

1.1. Product quality and consumer perception

The quality of fruits and vegetables constitutes a dynamic composite of the physicochemical properties pertaining to horticultural commodities and consumer perception. The difficulty in coining a universal definition of quality in reference to horticultural products stems to an extent from the multiple stakeholders partaking to the horticultural supply chain, each acting essentially as a consumer in relation to the preceding chain member (Abbott, 1999; Watada, 1980). Attempts at defining quality often discriminate between intrinsic characteristics inherent to the nature of the products, dictated by genotypic, agroenvironmental and postharvest factors, and extrinsic characteristics influenced by socioeconomic and marketing factors which condition consumer perception of the products and formulate quality prototypes (Schreiner et al., 2013). Consumer acceptability for the products is reflected ultimately in sales figures, with recurrent purchase of particular products constituting an unequivocal measure of their quality (Kader, 2008). Indeed, consumer studies relative to horticultural products have indicated that when price varies within the anticipated range, purchase decisions are based on perceived quality rather than price (Harker et al., 2003). However, consumer needs and perception of quality are not static but rather evolve along with changes in gender roles, increasingly individualized lifestyles, time allocated to food preparation and in response to such extrinsic factors as product marketing, population flux, gastronomic trends, health concerns and food scandals (Jabs and Devine, 2006).

It has been proposed that product-oriented and consumer-oriented approaches at defining quality in horticultural products promote different attributes of quality, with the former laying emphasis preferentially on quantifiable traits relating to appearance and shelf-life, and the latter on consumer behaviour and needs (Shewfelt, 1999). It may be easily construed that neither approach alone can produce an adequate definition of quality: instrumental quantification of key quality traits provides essential tools for standardization and monitoring of fruit quality along the horticultural supply chain, whereas an understanding of actual consumer needs and purchasing behaviour is

* Corresponding author.
E-mail address: m.kyriacou@ari.gov.cy (M.C. Kyriacou).

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necessary for supplying pertinent products of optimal quality. Promoting the daily consumption of fresh fruits and vegetables requires a fundamental understanding of consumer perception of quality to guide our attempts at optimizing and diversifying quality along the horticultural supply chain. This necessitates the linking of recent advances in instrumental quantification of quality attributes with quality as perceived by consumers. The lack of external validation in instrumental quantification of quality attributes is an important issue raised eloquently by previous researchers (Schreiner et al., 2013). Lack of external validation means possible dissonance between what is measured and what is actually perceived by consumers. In simple words, we have a plethora of reports on how various factors influence particular quality aspects of fruits and vegetables, e.g. firmness, colour, soluble sugars and acids, or volatile fractions, but we have limited understanding of the impact that variation in these attributes has on perceived quality. Moreover, we have a limited understanding for the relative weight each of these aspects has on perceived quality across different horticultural commodities, and also a limited understanding of their synergistic function in eliciting psychophysical and psychochemical sensory responses (Bartoshuk and Klee, 2013). Flavour is an integrated sensation of taste and olfaction. Basic taste characters (sweet, sour, salty, bitter), combine with retronasal olfaction, elicited by volatiles released from foods during chewing and swallowing and forced into the nasal cavity from the rear of the palate, to produce a central flavour sensation in the brain (Bartoshuk and Klee, 2013). As opposed to the pleasure elicited by taste, olfactory pleasure is considered largely acquired and subject to conditioning effected through pairing olfactory stimuli with other sensory stimuli of hedonic impact. Olfactory stimuli may even function as cues to nutritive value as many flavour volatiles are derived from essential nutrients (Goff and Klee, 2006). Sensory assessment of quality using trained sensory panels is time-consuming and costly therefore it is scarcely coupled to instrumental analysis; however, combined sensory and instrumental assessments are imperative for establishing an interpretive framework for the latter and facilitating their extensive use in constructing predictive models of quality for horticultural products in the supply chain. This is aptly exemplified by the recent advances in mass spectrometry analysis which provide highly analytical compositional profiles of the volatile fractions in fruits and vegetables; however, they generally lack a resilient basis for interpreting the relative abundance of particular components in terms of actually perceived aroma (Saftner et al., 2007). Ultimately, quality is perceived as a sensory experience not in parts but as a whole which translates to the degree of consumer satisfaction and influences future purchasing behaviour.

Arguably, a heavily product-oriented approach toward quality of horticultural products has been propelled mainly by advances in postharvest physiology and technology (Shewfelt, 1999). Key first-level attributes that momentarily influence purchase decisions, such as size, shape, colour, absence of defects and firmness, have been disproportionately associated with quality. Preservation of visual quality has been the main target of postharvest technological advances and recommendations at the expense of flavour and nutritional value. Likewise, plant breeding has aimed emphatically at improving yield, disease resistance and postharvest life (Bai and Lindhout, 2007). It may be argued that progress in these respects has been made at the expense of quality, as breeding for shelf-life may elicit adverse pleiotropic effects on desirable sensory attributes, such as texture and flavour (Causse et al., 2002). However, fruit and vegetable consumption is driven primarily by flavour, delivered at affordable prices. Visual quality and flavour quality usually do not coincide as postharvest life based on flavour is shorter than postharvest life based on appearance but cultivar selection is primarily based on the latter (Kader, 2008). For instance, the production of volatile flavour compounds in melon genotypes is associated with ethylene-dependent pathways and with dramatic textural changes, rendering short shelf-life genotypes the most aromatic (Pech et al., 2008).

1.2. Quality standards and regulations

The emphasis on visual attributes is also evident in the current regulatory context for fruit and vegetable quality which comprises crop-specific class standards based on key visual and limited organoleptic criteria [Commission Implementing Regulation (EU), 2011]. These standards essentially constitute mere acceptability thresholds and provide practical, effective and for the most part non-destructive means to facilitate product standardization, ensure product homogeneity and ease the logistics of the supply chain. They address quality aspects of concern primarily to chain intermediates and less so to the ultimate consumers who experience the products organoleptically. The current regulatory context for quality standards denominates quality classifications for fresh fruits and vegetables based mainly on product integrity, the degree of visible defects and on simple morphometric characteristics of the products. Reference to compositional aspects that reflect organoleptic value is limited to the soluble solids content (SSC) and the titratable acidity of the juice of very few products (e.g. citrus, grapes). However, even the limited references to criteria such as the SSC are not intended to promote excellence in product quality but only to provide a questionable base reference for acceptability. For example, the United Nations UNECE Standards for Watermelons (UNECE, 2015) and the U.S. Standards for Grades of Watermelons (USDA, 2006) dictate that the refractometric index (SSC) obtained at the middle point of the fruit must be equal to or higher than 8 °Brix for taste to conform to a sufficient state of ripeness and comply to USDA optional “good internal quality” standard. Yet experienced researchers and extension specialists would argue that acceptable organoleptic quality in watermelon requires a SSC of at least 10 °Brix (Kyriacou et al., 2016, 2017; Maynard et al., 2002).

Further to the above, current regulations fail to address complex compositional aspects relating to the organoleptic, nutritional and bioactive value of fruits and vegetables, which are increasingly attracting consumers’ attention (Schreiner et al., 2013). The gap between regulatory standards and consumers’ expectations is more effectively addressed by commercial quality assurance and standardization systems that encourage the collaboration of producers and marketers and facilitate the sourcing of superior flavour quality products across seasons and production areas in the context of consolidation and vertical integration in the global fresh produce market (Kader, 2008). On the other hand, the consumers’ perspective on quality is evolving beyond traits akin to mere sensorial satisfaction to encompass the nutritional and the functional aspects of foods related to their phytonutrient content. Thus the terminology of quality must expand to cover functional quality aspects which currently lack a consistent regulatory context (Vergari et al., 2010). It is also important to address socioeconomic and environmental factors that underlie our perception of quality. High visual quality standards arguably increase the volume of food waste and condition consumers’ expectations for visually impeccable horticultural products in a world where food security emerges as a colossal issue while currently about one third of world food production is never consumed (Gustavsson et al., 2011). Consumers’ expectations for flavour are met with discontent partly because they have been trained to construe aesthetic homogeneity as tantamount to quality. Promoting the nutritional and functional aspects of quality also requires that consumers expand their perception of palatability beyond carbohydrate-rich products to cherish the nutritional value in fruits and vegetables of more astringent, bitter, sour and pungent flavours. Studies on consumer behaviour have demonstrated that increased concentrations of phytonutrients with chemopreventive features characterise foods most aversive in taste and this constitutes a challenge for the diversification of plant genetic resources used in food production (Drewnowski and Gomez-Carneros, 2000).

Notwithstanding the above considerations, addressing issues of organoleptic quality deterioration is undoubtedly critical for increasing the consumption of fresh fruits and vegetables, and efforts must be