Chapter 2
Quality and Potential Healthy Traits in Vegetables and Berries

Paolo Sambo and Carlo Nicoletto

Abstract In recent years, the sensitivity of consumers and producers towards the environment and health topics has increased significantly, and these issues are involving more and more the agricultural world. Much has been done in terms of cropping systems and technology, but the issues relating to the quality and nutritional value of products turn out to be more complex and sensitive. In this regard, the consumer is more aware of these issues thanks to the many suggestions offered daily both in the health and in a healthy diet.

In this sense, this chapter aims to provide a current status of the concept of quality in the context of vegetable products and highlight its importance especially in order to promote vegetables by improving the final consumer diet. In this regard, the indicative pattern of the chapter could include three main sections. The first concerns about the identification and exploration of the quality concept and its evolution over time with respect to all aspects that contribute to its perception by the consumer. Moreover the technical-agronomic factors and environmental factors that determine the product quality associated with pre-harvest until the ripening stage will be considered. Finally, in the last section of this chapter, we will refer to the quality maintenance in post-harvest considering the evolution of multiple physiological aspects (antioxidants, phenols, vitamins, macro- and micronutrients, etc.) to the hypothetical purchase of the product by the consumer. During all the steps described so far, in which quality is involved, we will consider the potential health traits and benefits relevant to the health of the consumer trying to provide a clear and complete view in this research field.

Keywords Food quality • Nutrition • Antioxidant • Phenols

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2.1 Introduction

The term "quality" and the different meanings that this word may assume have for some years occupied a key role in any discussion on the production and marketing of goods and services. As regards vegetables for fresh consumption, the concept "quality" has changed profoundly, passing from just commercial and organoleptic parameters to cover a much wider range from the sanitary to intrinsic health and nutritional characteristics, and also the "ethical" aspects linked to the production process. At international level, the accepted definition is "*the set of priorities and characteristics of a product or service that confer on it the capacity to satisfy the expressed or implicit demands of the consumer*" (Peri 2004). This is a wider concept than the traditional definition which referred principally to the aesthetic characteristics of the goods, rendering it necessary to adapt production to a system of quality that can meet all the needs of the market.

The fruit and vegetable production sector is no exception to this trend. In times of rapid social and economic changes and market globalization, success in international competition depends mainly on the quality of the produce.

It is therefore important to investigate the significance of quality and understand how this changes in the different circumstances and in the ambits of the actors in a supply chain that begins with the producer and ends on the consumer's table. Quality only exists in the mind of the observer, i.e. the consumer, and will consequently change over time with a frequency and intensity that depend on the consumer's developing tastes. In this context it would seem appropriate to discuss how the aspects of quality, applied to the fruit and vegetable market, have evolved over time, and which prevalent directions will be taken in the near future to comply with a consumer demand that is often steered by the advertising and commercial policy of the large-scale retail trade.

The quality of a product is the result of a series of factors, some of which are perceptible but cannot be measured and are therefore subjective (e.g. taste, aroma, etc.) and others that are measurable and consequently objective (e.g. sugar level, acidity, concentration of polyphenols, antioxidants, vitamins, nitrates and others).

Within this general context a precise definition of quality is not easy in the horticultural sector, as the food products (raw, cooked or in some way prepared and conserved) are obtained from annual or perennial herbaceous angiosperm plants that belong to more than a hundred species, as well as fungi. It should also be kept in mind that within the same family the parts of plants consumed are at times drastically different (e.g. flowers, leaves, shoots, stalks and roots in the *Brassicaceae*). In addition, within the same species, there may be a large number of cultivars that have the same edible organ but with different morphological characteristics. For example in the *Solanaceae*, the tomato may have berries coloured yellow, red or purple, of a globular shape (round or flattened, smooth or ridged), elongated (e.g. San Marzano), cherry or grape. In the *Cucurbitaceae*, melon fruits can be from more or less spherical to oval, a skin colour from green to red, with or without netting and more or less evident clove signs and a flesh colour from white to yellow to different shades of orange. In the same family, the courgette has fruits that are more or less long or spherical, with skin colours from different shades of green to pale yellow, uniform or striped in various ways. Similar considerations can be made for the watermelon which has fruits that, in addition to differing colour and shape, can reach unitary weights from around 1 to 20 kg and more. From this summary it can be deduced that it is extremely difficult to identify generalizable qualitative requisites in botanical terms. Thus other parameters have to be identified so that homogeneous groupings can be made on which it might be easier to generalize a definition of quality.

The parameters that could allow sufficiently homogeneous classifications, used to guide the interventions destined to enhance the quality characteristics of the product, might, for example, be the type of marketable edible parts and the phenological stage at harvest.

In addition to this, there is an increasing need to adapt the productions to a quality system which can guarantee that all the requirements necessary to satisfy the demands of the consumer are present in the purchased good. In this case attention is paid to the genuineness, absence of treatment residues (pesticides), sanitary characteristics, healthiness, naturalness, seasonality and with a growing interest in produce from organic cultivations. Concerning the sanitary aspect, there are precise and accurate interventions which, when not statutory, are defined by the different businesses that commit themselves to undertaking appropriate methods of self-regulation of their activity following the HACCP methodology (Hazard Analysis Critical Control Point). This is done to provide guarantees for their clients, but also allows access to otherwise inaccessible markets. These certifications guarantee that at every step of the supply chain, which begins with the sowing of the crops and ends with the distribution and sale of the edible produce, all the technological and organizational measures have been implemented that are necessary to prevent possible health risks for the consumers. This new concept of quality involves all the protagonists who form the supply chain and, consequently, the interventions can no longer have the primary aim of resolving just the specific needs of the individual actor, but must fit into a much wider context in which the suggestions and requirements of the other sectors that take over in the various stages are also considered.

In order to facilitate an understanding of the entire supply chain quality, it is worth summarizing, in sequence, the succession of interventions during the salient stages of the itinerary that, starting with the choice of species to cultivate and the cultivar, ends on the table of the consumer. It is therefore obvious that there is an interaction of highly diversified and complex aspects. To simplify the various effects, it may be worth considering two stages, in the first of which the principal actor is the producer with his farm, while the second comprises the actors who will manage the produce in all the stages that must be passed through before reaching the end user, as shown in Fig. 2.1.

In the first stage, which is the time when the quality of the produce can be most directly determined, particular attention must be paid to the choice of cultivar, evaluation of the seed, preparation of the soil, planting methods and patterns,

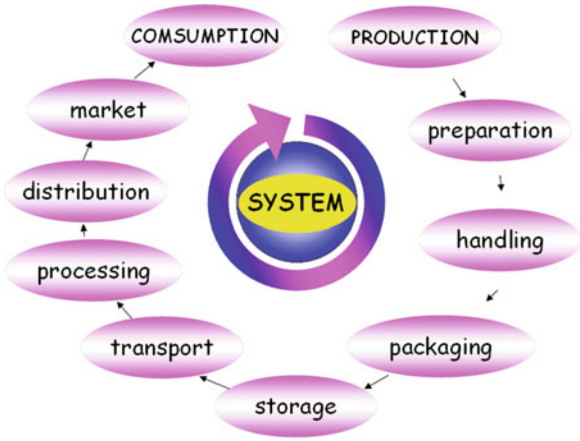

Fig. 2.1 Flow chart of the stages involved in the supply chain

fertilization, irrigation, pest and weed control or the guidelines for organic crops, until the most important goal is reached, the harvest. This is the moment when the production will be evaluated not only in terms of quantity, but more especially its quality, which will represent the maximum value reached with the technical–cultural methods applied. The second stage covers all the interventions necessary for product management; these include handling, transport, preparation, packaging, storage, transformation, distribution, the market and consumption. Extreme care must be taken in these steps because they can each have effects on the quality.

2.2 Some Chemical Components Determining the Quality of Vegetables

Currently, the high productions and vast areas growing horticultural crops cannot always guarantee a product with the characteristics that the market requires, especially in these last years. Consumers now demand a "high-quality" product from sundry points of view and, even better, one of "guaranteed quality". The concept of quality is very wide, difficult to define, firmly anchored to subjective evaluations and in continual evolution depending on the progressive shifts in the tastes, typical lifestyles and requirements of Western societies. According to an international definition, as previously mentioned, the quality represents "*the set of aspects and characteristics of a product or service that can satisfy the declared or implicit requirements*" (standard UNI EN ISO).

Quality can be divided into "structural quality" and "functional quality" (Mezzetti and Leonardi 2009): the former refers to the intrinsic characteristics of a product (e.g. sugar content in a fruit); the latter to the manifestation of these characteristics for the consumer (e.g. sweet taste of the fruit). In addition, reference has also been made more recently to the concept of "global quality", an expression that covers multiple meanings in which aspects regarding both the product and the process coexist. Indeed, quality changes according to the point of view: for the farmer quality means high yield, disease resistance, simultaneity of maturation, ease of harvest and good appearance; for the trader it means resistance to handling and transport; for the wholesaler the long storability is important and lastly the consumer is interested in the flavour, the right price, the absence of residues and high nutritional content, rather than the exterior aspect that attracted him up until a few years ago. There has also recently been a tendency to widen the concept of quality and food safety beyond the intrinsic characteristics of the product, by taking the quality of the production process into consideration (Abbott 1999; Rico et al. 2007). In the choices of the consumer, his taste perceptions and nutritional needs are now combined and matched with his expectations regarding respect for the environment, the biosphere and the guarantees offered by the producers (Peri 2004). Therefore, in addition to the expectation to eat a product with optimal organoleptic and chemical–nutritional characteristics, new elements have appeared on the horizon, which do not refer to the product itself, but relate to the environment and production methods.

These elements may regard tradition and culture (the importance of geographical origin and strong ties between local foods and customs), the environmental impact of the production process and elements linked to the honesty, transparency and ethics of the producer (Menesatti 2000).

The quality of fresh vegetables has been discussed in many studies in recent years. This is due to the fact that they are foods that regulate metabolic activity through their supply of water, minerals, vitamins, fibres and other nutrients. Vegetables are increasingly appreciated for their high content of substances like vitamin C and polyphenols, compounds that protect against the onset of various types of tumour, cardiovascular disease, premature ageing of the cells, etc. (Vinson et al. 2001).

Unfortunately, at times the horticultural sector does not fully satisfy the consumer demands because knowledge of this aspect is scarce or completely lacking for some vegetables, especially for those which are not universally known and appreciated. This limits the expansion of many horticultural products that, if suitably characterized from a quality point of view, could offer a higher profitability. Among the many parameters that characterize this aspect of vegetables, the most interesting health-wise are the total antioxidase capacity, total phenols, ascorbic acid, pigments, sugars and protein nitrogen, but the potentially harmful components like nitrates and nitrites must also be taken into consideration.

2.2.1 Antioxidants

Many of the phytochemical compounds in fruit and vegetables have an antioxidant function that can offer a basic protection against some of the most widespread illnesses, such as cardiovascular diseases, cancer and many other degenerative pathologies linked to ageing (World Health Organization 1990; Ames et al. 1993; Willet 1999; Chu et al. 2002). The term antioxidant generally means the property of a substance to prevent or inhibit oxidation, which is a chemical reaction that transfers electrons from a substance to an oxidant. These metabolites react with the free radicals produced by this reaction and thus interrupt the chain reactions that are initiated by intervening on the intermediate radicals, inhibiting other oxidation reactions and oxidizing in place of the oxidizable substrate. A wider definition of antioxidant is a substance that, added in low concentrations compared to that of the oxidizable substrate, can significantly delay or prevent the oxidation of that substrate (Cabras 2004).

The presence of antioxidants in food plays a significant role in the reduction of oxidative phenomena and in the relationship between this activity and the onset of pathologies such as arteriosclerosis (oxidation of the low density lipoprotein—LDL), tumours (oxidative damage to the DNA) and other pathologies, as has been demonstrated in epidemiological studies (Dalla Rosa 1996; Proteggente et al. 2002; Serafini et al. 2002; Kris-Etherton et al. 2002; Liu 2004). They can be divided into essential antioxidants, like some vitamins (A, C, E, folic acid), and non-essential antioxidants, including some secondary compounds of the plant metabolism (polyphenols, tannins, glucosinolates, metilxantine, ubiquinone, phytic acid, lipoic acid). Another classification takes into consideration the mechanisms of action of the antioxidants and, based on these, they are divided into primary and secondary antioxidants. The primary antioxidants are reducing substances, which oxidize in place of the food, thus protecting it from alteration; they are acceptors of free radicals and thus delay or inhibit the initiation or interrupt the propagation of the autoxidation reaction. The antioxidants of this type react with the lipid and peroxide radicals and convert them into more stable and non-radical compounds, adding a hydrogen atom. The secondary antioxidants are instead able to reduce the primary antioxidants, when these have reacted with the food, rendering them once again suitable to continue their activity. They slow down the speed of oxidation in different ways but do not convert the radicals into more stable compounds. The secondary antioxidants can chelate pro-oxidant metals and deactivate them (chelating antioxidants), restore hydrogen to the primary antioxidants (reducing agents), break the hydroperoxides down into non-radical species, deactivate the singlet oxygen quenchers, absorb ultraviolet radiations or behave as oxygen scavengers. These antioxidants are often defined synergically because they promote the activity of the primary antioxidants. It is plausible that the beneficial effects due to the consumption of plant products are determined by the presence of a mixture of antioxidant compounds that act in synergy, conferring a much higher antioxidant activity on the fruits and vegetables compared to the simple sum of the anti-radical action of the individual compounds (Tomás-Barberán and Espin 2001; Cabras 2004; Ismail et al. 2004).

The potential beneficial role of the antioxidant molecules is immediately understandable if we consider that our bodies are continuously exposed to the aggression of highly reactive chemical species that can damage cells and tissues, which are produced by the intermediate metabolism of oxygen and known as free radicals. Some of these substances are produced during the normal metabolic cycles, while others are related to lifestyle or the result of different pathologies (Fogliano 2009). The free radicals become harmful when their production is higher than the capacity of elimination by the natural defence systems. To counteract these negative actions, the human body has developed a complicated defence system that uses endogenous enzymes and numerous substances with antioxidase activity that are directly or indirectly supplied by the diet. In addition to the fundamental action performed by the enzyme inhibitors of oxidation, such as superoxide dismutase, catalysis and glutathione peroxidase, various compounds can interact with the reactive species of oxygen and have a regulatory effect. These include vitamins C and E, carotenoids and all the phenolic compounds.

As regards vitamins, fruit and vegetables are the primary source of vitamin C or ascorbic acid, a water-soluble molecule that performs multiple functions in the body. Being a powerful reducing agent, vitamin C exerts a strong antioxidant action, reacting rapidly with the free radicals in diverse reactions and oxidizing to dehydroascorbic acid. Together with glutathione, ascorbic acid is an important reserve of reducing capacity and is accumulated to a certain extent in the body. However, excessive amounts are immediately eliminated so it is important to have a continuous intake of vitamin C with the diet (King et al. 1994; Padayatty et al. 2003). Vitamin E is instead the principal vitamin with a lipophilic structure and for this reason it is indispensable for protection of the cellular membranes and other subcellular lipid structures. It has demonstrated a reasonable antioxidant activity thanks to its capacity to block lipid peroxidation. This property is due to its transformation into a stable radical compound, successively regenerated by the intervention of vitamin C and glutathione (Rimm et al. 1993; Balz 1999).

To prevent oxidation reactions it is important to have various molecules available with different reducing potential or anyway able to prevent oxidation with multiple mechanisms. For this reason the presence of the greatest variety possible of antioxidant molecules ensures the best protection in the various tissues (Fogliano 2009).

Agronomic practices, seasonality and genetic improvement can significantly influence the presence of elements with antioxidant activity in the plant products, as can the post-harvest treatments (Dalla Rosa 1996; Chassy et al. 2006; Shao et al. 2008; Björkman et al. 2011).

Among chemical compounds with antioxidant activity the phenolic compounds, or polyphenols, represent one of the most numerous and widely distributed groups of substances in the vegetable kingdom, with more than 8,000 known phenolic structures. They derive from the secondary metabolism of plants and are all characterized by the presence of an aromatic ring endowed with one or more hydroxylic group (Urquiaga and Leighton 2000). The structure of polyphenols varies from simple molecules, like the phenolic acids, to highly polymerized compounds, like the tannins (Vinson et al. 1998; Harborne and Dey 1989). For simplification, polyphenols can be split into two large families:

- *Flavonoids* that in their turn include the anthocyanins (red or blue pigments), flavanols (yellow pigments), flavones and flavonols (white or ivory pigments). The tannins (brown or blackish in colour) derive from the flavanols.
- *Non-flavonoids* or *phenolic acids* that can be found in the form of benzoic acids (e.g. gallic acid, catechic acid and cinnamic acids (e.g. caffeic acid and coumaric acid). These latter can combine with the anthocyanins and with tartaric acid, forming condensed polyphenols (Taiz and Zeiger 2002).

The flavonoids represent a vast family of polyphenolic compounds of low molecular weight, the majority of which are found in the outer layer of plant tissues (Clifford 1999; Chu et al. 2000). From the quantitative point of view the polymers of the flavonoids are of great importance, especially catechin. Vegetables, together with some fruits, are the principal food sources of flavonoids. There are various theories relating to their role in plants; the most credible are protection from UV-B rays and defence against pathogen attacks (Takeda et al. 1994). Because flavonoids also play an active role in the photosynthetic processes (Middleton and Teramura 1993), their quantity is influenced by exposure to light, rising with an increase in light intensity and especially UV-B radiation (Takeda et al. 1994).

2.2.2 Pigments

In addition to the chlorophylls, the main pigments present in plants, carotenoids and anthocyanins, are extremely important for plants and also for our bodies (Bartley and Scolnik 1995; Lila 2004, 2009; Pangestuti and Kim 2011). The carotenoids, orange and red pigments, are compounds belonging to the family of the tetraterpenes. The presence of conjugate double bonds allows them to easily accept electrons and therefore function as oxidation inhibitors. The carotenoids take part in the energy transport chain during photosynthesis, while in non-photosynthetic organisms they have an important role as antioxidants. The carotenes, formed just of carbon and hydrogen, and xanthophylls, also containing oxygen, both belong to this family. From the nutritional point of view it is important to distinguish between the carotenoids that are precursors of vitamin A (mainly beta-carotene) and the non-vitamins. The principal carotenes are lycopene and beta-carotene, while the xanthophylls include lutein and zeaxanthin.

2.2.3 Nitrates

Among the many bioactive compounds useful for the human body, some are a potential hazard. Nitrate (NO_3) is widespread in nature, in the soil, plants and water (Trinchera 2001; Addiscott and Benjamin 2005; Lundberg et al. 2004) and is the most important source of nitrogen for plants, which allocate a significant part of their carbon and energy reserves to its absorption and assimilation (Buchanan 2003). Nitrate is not introduced as such into the organic compounds, but must first be reduced to ammonium through a process in two stages. First of all nitrate is reduced to nitrite (NO_2) by nitrate reductase, then nitrite is reduced to ammonium by nitrite reductase (Buchanan et al. 2003) and lastly the ammonium is assimilated through various metabolic pathways in the organic compounds, first and foremost the amino acids (Gonnella et al. 2002).

For humans, the three main sources of nitrate are in the order: vegetables, water and salami/sausages (Santamaria 1997; Hord et al. 2009). In fact nitrate and more especially nitrite are used as food additives in prepared and preserved meats because of their antimicrobial action (Santamaria 2006). The presence of nitrate, especially in vegetables, is considered a serious threat to human health (Santamaria 2006).

From the toxicological point of view, nitrate in itself has an extremely low acute toxicity (Speijers 1996). The main problem is linked to the fact that in humans 5–10 % of the nitrate ingested is reduced to the more toxic nitrite in the saliva and gastrointestinal tract (Walters and Smith 1981) through the reduction from nitrate to nitrite by bacterial enzymes (Santamaria 2006). Even more worrying is the fact that nitrite can react with amines and amides to form N-nitroso compounds, which are toxic and can lead to serious pathologies in humans (Santamaria 2006). The principal effect produced by nitrite is oxidation of the haemoglobin in the blood, which is transformed into methaemoglobin, a compound no longer able to transport oxygen to the tissues. Lower oxygen transport has consequences, especially in babies up to 6 months old as it causes methaemoglobinemia, also known as “blue baby syndrome”, which results in the bluish coloration of the extremities (fingers, nose) due to the poor oxygenation of the blood (Santamaria 2006). To evaluate the carcinogenicity in laboratory animals, around 300 N-nitroso compounds have been studied: 85 % of the 209 nitrosamines and 92 % of the 86 nitrosamides have resulted as being carcinogenic in more than 40 animal species (Gangolli et al. 1994). These include mammals, birds, reptiles and fish, so there is no reason to suppose that humans would be the only ones resistant (Hill 1999). Numerous genetic, environmental and cropping factors influence the absorption and accumulation of nitrate in plant tissues. Among the studied factors, both the intensity and duration of light have been identified as the main influence on the nitrate content in vegetables (Santamaria et al. 2002; Pimpini et al. 2005; Nicoletto and Pimpini 2010). In fact, both affect the activity of nitrate reductase that can regulate the accumulation of nitrates as it stimulates the triggering of the nitrogen assimilation process. Essentially, the greater the light intensity and length of the photoperiod, the lower the content of nitrates in the plant tissues (Pimpini et al. 2005). A variation of the nitrate content in leaves during the day derives from this, with the minimum values found around sunset and maximum at dawn (Minotti and Stanley 1973). This is of practical interest as it suggests the best times for harvesting, which should not be underrated given that the nitrate content is now one of the main characteristics evaluated within a context of high-quality production.

Temperature can also affect the nitrate concentration in the tissues, as it influences the processes of absorption, translocation and assimilation, often in a combined way (Gonnella et al. 2002). Behr and Wiebe (1992) found that photosynthetic activity is inversely correlated to the temperature of the environment, with an increase in nitrate accumulation as the temperature rises. In rocket, for example, the results from trials conducted by Ventrella et al. (1993) showed that the leaves had higher nitrate contents at a temperature of 15 °C than 10 °C. Another factor to be taken into consideration is the water content in the soil. A good availability of water favours the absorption of nitric ion and its accumulation (Paradiso et al. 2001), but it can also increase the loss of nitric nitrogen by percolation towards the water soil layer (Patruno 1987). Furthermore, according to Maynard et al. (1976), water stress should be avoided because, in these conditions, the plant continues to absorb nitrate even when the nitrate reductase activity has already been interrupted and this causes an obvious increase in the nitrate concentration in the tissues. Lastly, post-harvest storage also has a strong effect on the nitrate content in the edible parts (Pimpini et al. 2005). In general, high temperatures, scarce oxygenation (atmosphere rich in CO_2) and high relative humidity increase the formation of nitrites (Santamaria et al. 2002).

Nevertheless, the most important cropping factor that can determine the amount of nitrates in plant tissues is nitrogen fertilization. Different aspects linked to fertilization can assume a determining role in the accumulation of nitrates in the edible parts of vegetables. First of all, it has been found that the nitrate concentration generally increases with the increased availability of nitrogen in the fertilizer (Bonasia et al. 2002). However, a high availability of N does not always correspond to an increase in production (McCall and Willumsen 1998). On the contrary, the plants continue to absorb nutritional elements in excess, storing them in the vacuoles, in order to still guarantee growth when the amounts of fertilizer diminish (Koch et al. 1988). This leads to an excessive accumulation of nitrates, a condition that is difficult to verify if it is not a soilless crop. In addition to nitrogen dose, the NH_4/NO_3 ratio has particular influence. The higher the ammoniacal rate, the lower the content of nitrates (Pimpini et al. 2005). The problem is that NH_4 is not the form usually preferred by plants (Salsac et al. 1987); moreover, if absorbed in excess, it can cause toxicity.

Regarding fertilization type, the slow-release fertilizers, given the risks of the release of nitrogen, should only be used after a careful evaluation of the application time and length of the cropping cycle to avoid high nitrate concentrations in the plants at harvest (Pimpini et al. 2005). With reference to planting density, an excessive number of plants per unit surface area must be avoided because the competition leads to a reduction of the light intensity at crop level. High densities also result in phenomena of high growing, with an abnormal lengthening of the leaf and an increased proportion of petiole, where the greatest nitrate concentration is found, in the edible product. Indeed, it has repeatedly been proved that the nitrate content varies in the different parts of the plant in this decreasing order: petiole, leaf, stem, root, inflorescence, tuber, bulb, fruit and seed. The different capacities of nitrate accumulation may be correlated to the localization of the nitrate reductase enzyme as well as to the different level of nitrate absorption and transfer in the plant (Santamaria 2006).

At least another two factors influence the nitrate content in vegetables: the botanical family and type of leaf. Regarding the former, the vegetables that accumulate more nitrate belong to the families of the *Chenopodiaceae* (e.g. spinach), *Brassicaceae* (e.g. white cabbage), *Apiaceae* (e.g. carrot) and *Asteraceae* (e.g. radicchio and lettuce) (Santamaria et al. 1999). As regards the latter, the inner leaves of lettuce accumulate less nitrate than the outer leaves. This may be due to the fact that the outer leaves have lower photosynthetic efficiency than the inner ones and contain larger vacuoles (accumulation sites of the nitrates) (Santamaria et al. 1999).

At regulatory level, given the fact that vegetables provide the most significant contribution to the intake of nitrates, the European Commission's Scientific Committee for Food (SCF) proposed the introduction of maximum limits for nitrate content and the adoption of cropping techniques aimed at reducing its concentration in vegetables (Santamaria and Gonnella 2001). Starting from the SFC proposals, and in order to protect public health, the European Commission Regulation no. 194/97 came into force on 15 February 1997, giving the maximum acceptable nitrate contents in lettuce and spinach in all states of the European Union (Santamaria et al. 2002). The regulation set higher nitrate levels for crops grown in winter than those in summer. For lettuce, higher limits were given for crops grown in the greenhouse with respect to outdoor crops (there is higher light intensity and lower temperature in the field; consequently the nitrate content is lower). On 2 December 2011 the European Commission substituted Regulation no. 1881/2006 with Regulation no. 1158/2011. This introduced some changes and set new maximum acceptable limits for the nitrates contained in the large leaf vegetables, such as spinach and lettuce. The limits are expressed in milligrams per kilogram of fresh produce and vary from 2,000 mg for lettuces grown outdoors to 4,500 mg for lettuces cultivated in a protected environment. This new regulation lays down that the member states of the Union must make regular checks on the nitrate content in vegetables, in particular green leaf vegetables, communicating the results to the Commission by 30 June of each year. In addition, the Department of Community Policies and the SCF have established an Acceptable Daily Intake (ADI) for NO_3 that should not be above 3.7 mg kg^{-1} of body weight.

2.3 The Quality as a Function of the Process Variants

As many factors affect the quality of products as those that control the yield levels. Their effects on the quality parameters can appear in different and sometimes contrasting ways. Within the same crop, in fact, the product quality depends on genetic factors, environmental factors, agronomic practices and aspects connected to the harvest and post-harvest stages. In general these factors may have direct or indirect effects in relation to their influence on the processes of assimilation, water absorption, nutritional status and the repartitioning of the photosynthates in the edible parts of the plant (Mezzetti and Leonardi 2009).

2.3.1 Genetic Aspects

For fruit and vegetable crops, the choice of genotype has always been of primary importance in relation to the effects on the quality characteristics of the produce that derive from the continual diffusion of new cultivars characterized by a high productive potential or suitable to cope with specific stress conditions. The variability of the quality due to genotype can be one of the most direct strategies for producing quality characteristics that meet specific consumer demands.

In the case of programmes aimed at enhancing the nutritional quality, for example, it would first be necessary to understand the processes that determine the efficacy of the bioactive compounds; therefore, it is indispensable to identify them chemically and verify their stability in the various conservation stages (Finley 2005).

The nutritional quality of different fruit and vegetable species can be enhanced using a traditional approach of genetic improvement only if genetic resources are available that can provide effective progresses in the different generations of crosses. The transgenic system has been successfully applied for some vegetables such as tomatoes (Davoluri et al. 2005) and this demonstrates the possibility of using these technologies to increase the content of specific bioactive components in the plants even if the interventions are rather complex.

2.3.2 Climate

Apart from what has already been reported for nitrates and nitrites, the variability of the climatic conditions is undoubtedly an important parameter for product quality. Climatic factors can have effects on the assimilation processes and nutritional status of the plant (Anttonen et al. 2006). Furthermore, the creation of "modified" climatic conditions through the use of more or less advanced protected environments may also have effects on the quality of the produce.

Among the many aspects that define climate, light and temperature play an important role in influencing quality because they interact strongly with the biochemical processes of the plant (Wang et al. 2003). They have different effects on the assimilation processes, because high light levels favour the accumulation of photosynthates, whereas high temperatures accelerate their demolition.

The influence of these two parameters on the quality must be considered in terms of the many definitions and attributes of quality. Extreme temperatures, for example, can have effects on the processes of macro- and micro-sporogenesis (Subodh and Munshi 2001), assimilation (Zhang et al. 2007) and the synthesis and demolition of pigments (Hamauzu et al. 1994).

Instead, low light intensity can have positive effects on some quality parameters in leaf vegetables (e.g. high wateriness of the tissues, attenuation of the green colour, etc.), while it can worsen the health characteristics of the produce because of the high nitrate accumulation (Santamaria et al. 2002; Santamaria 2006). The photoperiod is also of interest for some horticultural products (e.g. radicchio) as it may be the determining factor for phase transition, with a consequent decline in the product quality due to the plant going to seed (Pimpini et al. 2007; Pimpini and Nicoletto 2008). Relative humidity can also be a critical factor for the quality because it can determine a slowing down or activation of water exchange and its different allocation in the various parts of the plant (Leonardi et al. 2000).

2.3.3 Fertilization and Irrigation

Relevant effects on the quality of horticultural produce are mainly exercised by irrigation and fertilization (Ferrante et al. 2008). A regular water supply generally improves their quality through an increased water content in the edible parts. Yet a high water content may, in some cases, compromise the storability of the products or their tastiness. In general lines it can be stated that the quality is impaired by a lack of water for the species with vegetative organs and by excesses for those with reproductive organs (La Malfa 1988).

The effects of mineral nutrition depend on the role which the different elements have on the plant metabolic processes that synthesize and translocate the many biochemical compounds. If on the one hand, high fertilizer doses may be the prerequisite for an improvement in the positive factors of quality, on the other they may also involve the accumulation of nitrates in the edible parts (Malaguti et al. 2001).

2.3.4 Harvest and Post-harvest

The aspects that affect quality undoubtedly include those relating to the harvest and post-harvest. In the former case these refer to the maturation stage of the product, environmental conditions and harvesting methods. For the majority of fruit and vegetable products, the best quality characteristics are reached at the time of harvest; in the successive stages there is a progressive decline of the quality that can only be slowed down with opportune conservation strategies. Therefore the storage conditions and processing techniques can be of great importance during post-harvest as the products may suffer mechanical damage or pathogen attacks that alter the metabolic situation of the product (Almirante and Colelli 1994).

From what has been described so far, the need emerges for the horticultural sector to adapt to the new scenarios that have been appearing in the last years, through technical-agronomic and organizational innovation, as well as paying increasing attention to consumer expectations. Indeed, consumers are showing a growing mistrust of products that come from a production process characterized by a high level of intensification. In addition, they are increasingly aware of healthy products, obtained with eco-compatible techniques. These interests are due to the above-cited progressive change that is taking place in the concept of quality for horticultural produce. Therefore, one of the main aims to pursue in order to maintain the competitiveness of the sector is that of the qualification and characterization of the productions.

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