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Pre-harvest factors influencing the quality of berries

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ABSTRACT

Quality of berries is a difficult concept to describe objectively. The aim of this review is, to better define the concept of quality in berries, and summarize the main pre-harvest factors that influence quality of the fruit. Berry quality could be defined as a set of agronomic/commercial, organoleptic and nutritional qualities: the first one comprising of characters that belong to the adaptation of the plant to specific cultivation such as fruit size, plant yield, harvesting speed, and resistance to pests and diseases. Organoleptic quality is the main set of characteristics generally related to quality attributes that are recognizable through the five senses of the consumer. Finally, nutritional quality is the "hidden" quality present in berry fruits, that comprises all the macro- and micro-nutrients, vitamins and bioactive compounds.

Not only are these characteristics very variable among different species, but also among different cultivars within the same species. This kind of variability is ascribed to the category of genetic factors. The adaptability of berries to different climatic conditions (different latitude, soil conditions, production cycle, light exposition, etc.) represent the environmental factor that influence fruit quality. Finally, also the so called agronomic factors, related to the cultivation systems (open field or protected or soilless cultivation, organic or conventional cultivation), fertilization, water stress and salinity, and fruit harvest, influence the final quality of the berry fruits.

1. Introduction

Among fruits, the so-called "berries" have been consumed since many years, in particular in the northern latitude countries, where there is limited availability of other fruit and vegetable species. The term "berry" or "red fruit" indicates small fruits that grow in wild bushes, could be sweet or bitter, with a juicy pulp and an intense coloration ranging from red to purple/blue, rarely it is possible to have white fruits (Hidalgo and Almajano, 2017). The most common berries worldwide are cranberry, blackberry, blueberry, raspberry and strawberry, with elderberries, mulberries and other less common red fruits being specific of some particular environments.

In the last decades, breeding programs on fruit plants focused their priorities on the diffusion of new berry cultivars adapted to different climatic conditions and cultivation systems, with high yield, fruit size and firmness, resistance to pathogens and transport damages, and longer shelf life. Besides the agronomic performance of the plant, the sensorial traits of the fruit have now an increasing priority in many breeding programs. In fact, consumer quality acceptance is generally related to specific perceived organoleptic traits such as fruit color, shape, acidity and sweetness, combined with flavor and aroma determined by volatile compounds. All these quality traits are controlled by a complex genetic background and frequently associated with negative agronomic characters, such as, for example, less fruit firmness, fruit size or productivity. Long term breeding programs can lead to the release of more improved cultivars that are able to adapt to different climatic conditions and cultivation systems by maintaining high quality standards even at long distance commercialization of the fresh product.

Recently, also the nutritional value of berries, intended as the content of bioactive compounds with healthy effects on the final consumer, is being considered to better characterize the fruit quality. These kind of parameters belong to the so-called nutritional quality and they are of primary importance, together with all the other quality characteristics, existing in most of the berry breeding programs. In fact, the ultimate goal for the breeders is the obtainment of new cultivars with highly resilient plants, to low input cultivation systems and high adaptability to future climate scenarios, and able to bear high yields of organoleptic and nutritional quality fruits (Feliziani et al., 2016).

All these improvements, including the increase of specific bioactive compounds in berries (such as micronutrients, ellagic acid, vitamin C, phenols and folates) can be achieved through the classical genetic approach, but for some traits it is now also possible to use molecular

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markers assisted selection or other new biotechnological breeding techniques (Davuluri et al., 2005; Mezzetti, 2013; Limera et al., 2017). Micronutrients and phenolic compounds concentration in berries, as well as commercial and organoleptic attributes, have been reported to change according to many pre-harvest conditions, such as genotype, environment, and cultivation techniques (Cordenunsi et al., 2002; Kafkas et al., 2007). Some authors underlined how the genetic background of a berry species is the most important factor that affect the fruit quality (Milošević et al., 2016), in particular regarding the sensorial and the nutritional quality. Other authors have also demonstrated the strong influence of the genotype on the quality of different berry fruits, e.g. in black currants (Vagiri et al., 2016), blueberries (Balducci et al., 2016), and strawberries (Capocasa et al., 2008; Diamanti et al., 2012).

Clearly environmental factors also have an impact on important traits of berry quality. In fact, according to Karppinen et al. (2016a), the composition of phenolic compounds in blueberries can be affected by environmental factors such as light conditions and temperature; other authors have also underlined the importance of climatic and environmental factor in influencing the overall berry quality (Uleberg et al., 2016; Vagiri et al., 2016). The cultivation practices have also been considered as crucial for the quality of berry fruits, as recently demonstrated by Valentinuzzi et al. (2015).

The understanding of the effects of pre-harvest factors on the final quality of berry fruits could lead to the adoption of the best practices for increasing the overall quality of fruits.

The purpose of this review is to describe the main descriptors of berry fruit quality (Fig. 1) and how berry quality is influenced by pre-harvest factors such as genotype, environment and agricultural practices, as previously indicated for fruits and vegetables in general (Kyriacou and Rouphael, 2017).

1.1. Berry plant yield efficiency

Plant yield is the amount of fruits with commercial value harvested for each production cycle. Usually, this is the first parameter that a grower takes into consideration in the decision to grow a new cultivar. Furthermore, the harvesting facility is another important parameter, which indicates if a cultivar can reduce labor costs, the most important cost for all berries. Clearly of high importance is plant adaptability to different pedo-climatic conditions and resistance to pest and pathogens. These traits are the priority to reduce inputs and increase plant yield efficiency.

The traits mentioned above are more suitable for the evaluation of the plant yield efficiency. Among these, fruit size is certainly one of the most important trait in the selection of new genotypes. The cultivation environment strongly influences this parameter. The contribution of the parents to the fruit size can be estimated in case of a high number of progenies (Gilbert, 1967). The commercial standard size of berry fruits obviously depends on the species of fruit. The fruit size is evaluated through the implementation of some different parameters:

- Fruit Weight: indicates the average weight of a representative sample of fruits and refers to the dimension of the fruit;
- Fruit Length: indicates the average size on the longitudinal region of a representative sample of fruits;
- Fruit Diameter: indicates the average size around the equatorial region of a representative sample of fruits.

For berries, the increase of fruit weight is important to reduce production costs, in particular labor costs. In strawberries, berry fruit size has increased a lot thanks to breeding, so that for some cultivars the primary fruit can reach so high dimension not always appreciated by the consumer as it is considered artificial. While, growers are requesting them so to highly reduce harvesting costs. Length and diameter defines the final shape of the fruit consequently, defining the appearance of the fruit requested by the consumer.

1.2. Berry fruit organoleptic quality

The evaluations of sensorial and organoleptic traits are based on standard evaluation methods, which have been well described and well characterized. The fruit shape is strictly related to the fruit variety, and it is usually evaluated by descriptors in which the fruits have to be identified. The fruit color is a primary trait, which is fundamental in attracting consumers' interest. Clearly, the fruit color has to be representative of the specific berry species. Usually, fruits with a brighter color are more appreciated by the consumer than paler fruits. Some consumers have been described as neophobic (Raudenbush et al., 1998) meaning, they are not confident with food products that do not possess typical characteristics. This has been evidenced in the case of kiwifruit with yellow flesh by Jaeger et al. (2002). In larger red fruit, the color is evaluated through the analysis of the background color and the increasing of red/orange overcolor during ripening which improves the appearance of the fruit. Generally, in berries fruit color shift directly from green to colored (red, orange, blue, purple, depending to the type of berry) during ripening. In strawberry, in particular, the fruit become white before turning red and some cultivars maintain a white neck. The type of color is determined by the pigments (anthocyanin, phenols, etc,) accumulated in the fruit skin cells. Fruit color is clearly determined by the genotype but also highly influenced by the environmental conditions and maturation stage. Besides the external part of the fruit, the flesh is also evaluated for its color, even if this is not a parameter directly assessable by the consumer in the market. The interest in the fruit flesh color, in fact, has only increased recently, given that the color of the pulp is directly influenced by the amount of colored pigments like anthocyanins present in the fruit.

Another parameter of high interest is the firmness of fruit skin and

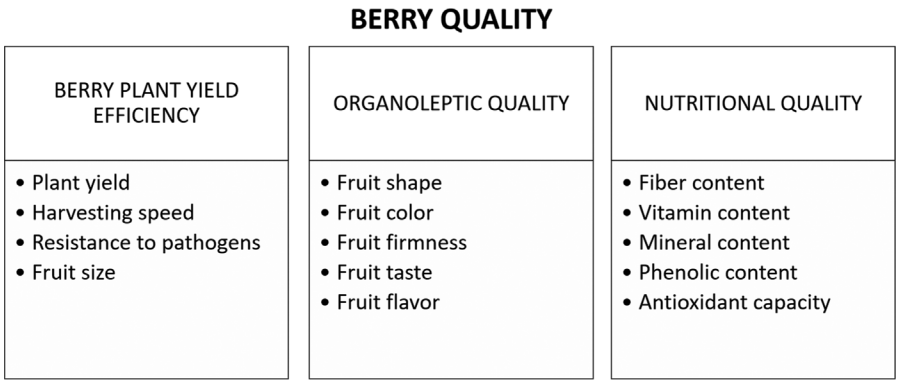

Fig. 1. Main descriptors of the concept of berry fruit quality.