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Review

The quality of asparagus as affected by preharvest factors

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ABSTRACT

Asparagus quality is very important for both growers and consumers. Among the commercial grading standards, the appearance (shape, size and color) of the spear is the most critical quality attribute. However, organoleptic attributes (texture, taste, aroma, flavor and bitterness) determine whether asparagus is accepted or rejected by the consumer, while the presence of bioactive compounds, beneficial for human health, is becoming increasingly valued. This review details the effect of genetic, environmental, agronomic and harvest factors on asparagus quality attributes, especially the organoleptic ones and describes the related physiological mechanisms. Finally, the challenges and opportunities related to develop branded asparagus as superior source of potential benefits to consumers' health are highlighted.

1. Introduction

Asparagus is grown commercially worldwide in approximately 190,000 ha (P. Beurskens, personal communication) with two main types of spears produced: green and white. In green asparagus production, the spears elongate following emergence from the soil in the presence of sunlight and, when they reach the marketable length (at least 19 but less than 28 cm), are harvested at or above ground level. On the other hand, the soil-mound method is the traditional method for the production of white asparagus (Siomos, 2003). In this method, soil mounds are prepared by ridging over plant rows to a 25–30 cm height above the crowns, 1–2 months before the start of spear growth. Thus, the spears are elongated inside the soil mound, in the absence of sunlight, and they are harvested just before they reach ridge surface. However, white asparagus may also be produced by other blanching methods, instead of soil mounding, such as under low or high tunnels established above plant rows covered with an opaque plastic film (Poll et al., 1990; Makus and Gonzalez, 1991; Jishi et al., 2012). The latter method is rapidly spreading for white asparagus production in some countries, such as Japan (Jishi et al., 2012). In this method, the spears elongate in a completely dark environment in air and are harvested at or above ground level, when they reach the marketable length. This harvest method, similar to the green asparagus, is easier compared to the traditional method.

Purple coloration due to anthocyanin biosynthesis in both green and white spears is considered an undesirable quality characteristic according to the existing commercial grading standards (Siomos, 2003). However, due to the potential health benefits of flavonoids, cultivars with completely purple spears have been developed (Benson et al., 1996; Fallon and Andersen, 1999) and are cultivated to a limited extend as a third type of asparagus.

The factors affecting the quality components of asparagus, e.g. genetic, environmental, agricultural and harvest, as well as post-harvest handling and conditions have been reviewed extensively by Lipton (1990). The present review summarizes research advances on the preharvest factors affecting asparagus quality since 1990.

2. Asparagus quality attributes

The appearance of the whole spear as well as of the tip and the presence of pesticide residues are used as primary aspects of judging asparagus quality throughout the production and marketing chain (Siomos, 2003).

According to the European Union grading standards (Commission of the European Communities, 1999), asparagus is classified into four groups according to spear color: white, violet, violet/green and green. The maximum spear length allowed is 22 cm for white and violet, and 27 cm for green and violet/green. The minimum spear diameter (measured at the mid-point of their length) must be for white and violet asparagus 12, 10 and 8 mm in extra, I and II class, respectively and 3 mm for violet/green and green asparagus in all classes. Even though 3 mm is the minimum spear diameter specified for violet/green and green asparagus, spears with such a diameter aren't really marketable. Extra class includes very well formed and practically straight spears, with closed and very compact tip. For the white asparagus, both the tip and shoot must be white, while the green asparagus shoot must be totally green. Spears slightly curved, with compact tip and a faint pink tint (for the white asparagus) or green for at least 80% of the shoot

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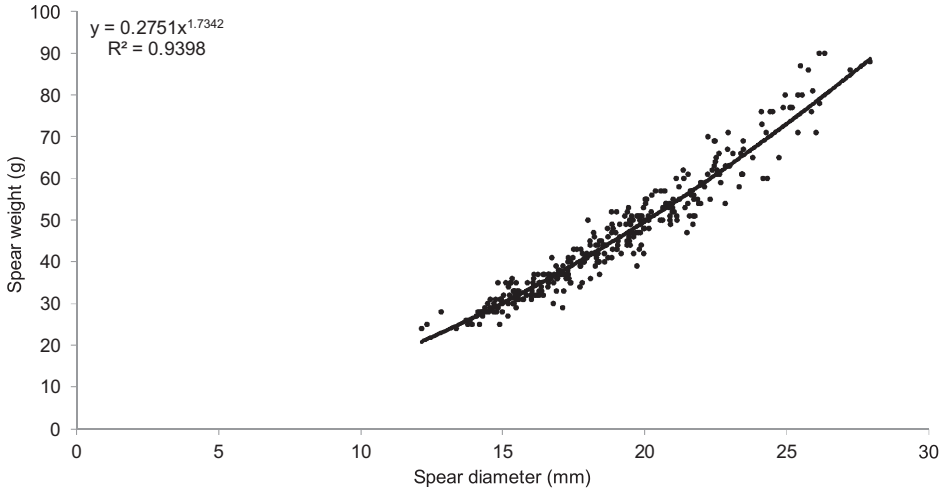

Fig. 1. Spear weight (measured at the mid-point of 21-cm length) as correlated with diameter in the range of 12–28 mm in white asparagus (n = 323). (Siomos, unpublished data).

length (for green asparagus) are classified as class I. Compared with class I, spears in class II may be less well formed, more curved, their tip may be slightly open, having a slight green tint (for white and violet asparagus) or must be green for at least 60% of the shoot length. The above regulation is no longer in force, since the grading standards of fruits and vegetables in the European Union are currently defined by the Commission Implementing Regulation (EU) No 543/2011 (The European Commission, 2011), which does not contain any special reference to asparagus, as the previous regulation of 1999 did. However, according to the current regulation, where specific marketing standards are to be laid down for individual products, the standards should be the ones adopted by the United Nations Economic Commission for Europe (UNECE) (United Nations, 2010), which are exactly the same with the previous regulation of 1999.

Spear size may be determined either by weight or diameter, as there is usually a high correlation between them (Fig. 1). However, according to the grading standards asparagus is classified according to spear diameter measured at the mid-point of their length. Thick spears (20–28 mm in diameter) are the highest priced class, since they are preferred by both the consumer, as they are more tender, easier to peel and leave less peel during preparation for consumption, and by the grower, as fewer spears have to be harvested per kilogram, thus reducing harvesting cost.

Texture is an important quality trait for all consumers, but taste, aroma, flavor and bitterness are also variably important. According to a study (Hoberg et al., 2008), the average consumer is able to recognize differences in the taste and flavor between white asparagus cultivars regarding bitterness, typical smell and sweetness. On the other hand, in recent years, consumer interest in functional food constituents beneficial to human health is constantly increasing, a trend that could affect their purchasing decisions (Chin and Garrison, 2008; Fuentes-Alventosa et al., 2008).

A total of 123 volatile compounds have been detected from fresh asparagus spears and 36 of them were identified (Ulrich et al., 2001; Ulrich and Hoberg, 2002) as being relatively similar in the spears of the three tested cultivars (one green, one green with light purple and one purple), but their quantities varied with the cultivar (Sun et al., 2002). Major compounds were C_6 aldehydes (hexanal and *trans*-2-hexenal, the most abundant ones) and alcohols (1-octen-3-ol, the most abundant one), both accounting for 85–91% of the volatiles; ketones, alkenes and terpenes were also detected, but in much lower quantities, with 2-pentyl-furan being the most common compound. The above compounds contribute to the characteristic aroma of fresh asparagus (the C_6 aldehydes contribute to the green grassy character, while 1-octen-3-ol is the dominant contributor to the characteristic mushroom aroma), and, together with sweet, sour and bitter components (sugars, organic acids, phenolics and saponins), contribute to the typical flavor. Eighteen sensory characteristics have been found to describe flavor characteristics (Hoberg et al., 1999). Although six different saponins have been detected in white asparagus spears (Schwarzbach et al., 2006; Brueckner et al., 2010; Dawid and Hofmann, 2014), their exact structure as well as their relative contribution to the perceived bitterness are still not known. However, some nitrogen and sulfur compounds in fresh asparagus are also important since, from their thermal degradation during the cooking process, different volatile compounds are generated which contribute to the aroma of consumed asparagus (Ulrich et al., 2001; Ulrich and Hoberg, 2002).

Bioactive compounds found in significant concentrations in asparagus and having attracted attention for their potential health benefits are rutin, a flavonoid derivative of the flavonol aglycone quercetin, protodioscin, a furostanol saponin, and glutathione, a biothiol (Mills et al., 1997; Chin et al., 2002; Demirkol et al., 2004; Schwarzbach et al., 2006; Chin and Garrison, 2008; Demirkol, 2009). Rutin has been found to be the most abundant flavonoid or polyphenolic compound in green asparagus (Chin et al., 2002; Wang et al., 2003; Maeda et al., 2005; Chin and Garrison, 2008; Fuentes-Alventosa et al., 2008; Guillén et al., 2008; Fanasca et al., 2009; Maeda et al., 2010; Motoki et al., 2012), while protodioscin accounted for the majority of the saponin content in white asparagus (Wang et al., 2003). Although protodioscin has been found in significant amounts in many plants, only white asparagus is regularly consumed vegetable among them (Chin et al., 2002; Chin and Garrison, 2008). Glutathione concentrations of 100–460 mg kg^{-1} fw have been reported with variation across cultivars, spear type and portion tested (Mills et al., 1997; Saito et al., 2000; Demirkol et al., 2004; Qiang et al., 2005; Drinkwater et al., 2014). According to these data, asparagus is classified as one of the richest in glutathione commonly consumed foods and is included in the top five among fruits and vegetables (Jones et al., 1992; Mills et al., 1997; Demirkol et al., 2004; Qiang et al., 2005; Zacharis et al., 2011).

Some other phenolic compounds such as anthocyanins, hydroxycinnamic and caffeic acids (Chin et al., 2002; Guillén et al., 2008), carotenoids and vitamins E and C (Chin et al., 2002; Demirkol et al., 2004; Fanasca et al., 2009; Lee et al., 2010) are also important from a nutritional point of view. Phenolic compounds (rutin, anthocyanins, caffeic acid, ferulic acid, hydroxycinnamic acids) as well as vitamin C (ascorbic acid), vitamin E (α-tocopherol) and glutathione contribute to the antioxidant capacity of asparagus (Chin et al., 2002; Rodríguez et al., 2005; Maeda et al., 2008; Rodkiewicz, 2008), which is classified accordingly as the richest or one of the richest among commonly consumed vegetables (Vinson et al., 1998; Pellegrini et al., 2003; Chun et al., 2005). The antioxidant capacity of green spears is primarily attributed to rutin (Maeda et al., 2005), while the contribution of