Postharvest Biology and Technology 102 (2015) 1–8

Contents lists available at ScienceDirect

Postharvest Biology and Technology

journal homepage: www.elsevier.com/locate/postharvbio

Comparison of industrial precooling systems for minimally processed baby spinach

Yolanda Garrido, Juan A. Tudela, María I. Gil *

Research Group on Quality, Safety and Bioactivity of Plant Foods, Food Science and Technology Department, CEBAS-CSIC, P.O. Box 164, E-30100 Espinardo, Spain

ARTICLE INFO

Article history:
Received 10 September 2014
Received in revised form 15 December 2014
Accepted 27 December 2014
Available online 14 January 2015

Keywords:
Cooling
Quality
Postharvest handling
Baby leaves
Hydro cooling
Vacuum cooling

ABSTRACT

Leafy greens including baby spinach are particularly prone to rapid dehydration. After harvest, leafy greens should be refrigerated as soon as possible to remove the heat from the field in order to decrease respiration rate and increase shelf-life. Delays between harvest and cooling should be avoided, especially during warm weather to avoid water loss. There is a wide range of precooling systems available for using in fresh produce. However, the best precooling system for baby leaves as raw material for the fresh-cut industry has not been well established. The aim of this study was to compare four precooling systems including room cooling (RC), forced air cooling (FAC), hydro cooling (HC) and vacuum cooling (VC) for their effects on quality and shelf-life of baby spinach. Two separate trials, one in winter and another in spring were carried out. Leaf water content increased after cooling in HC and VC but more significantly in winter while in spring, differences among treatments were not significant. The colour measured as chroma was more vivid in HC and VC just after processing but after storage, no differences among precooling treatments were observed. In winter, there were no significant differences in the respiration rate among precooling systems. However, in spring, HC and VC decreased respiration rate and modified less the headspace gas composition of the packages. *Pseudomonas* counts significantly decreased in HC and VC due probably to the washing effect of the leaf surface without promoting the growth of spoilage microorganisms. Surprisingly, visual quality was significantly lower in VC compared with the rest of precooling treatments due to the higher degree and number of damaged leaves. In conclusion, selection of the precooling system is critical during warm weather because of the high temperature at harvest. Hydro cooling is a good precooling system for baby spinach in spring as it decreases rapidly leaf temperature, decreasing respiration rate and extending shelf life. However, in winter, precooling systems are not as critical because the temperature at harvest was similar to the temperature reached after precooling.

1. Introduction

The production of ready-to-eat bagged salads continues to increase each year. The current demand for baby leaf salads is a result of consumer desire for healthy, fresh and appetizing food. In the market of fresh-cut products, mini or baby leaves are becoming more and more demanded. They are small size mature or immature leaves, multi and baby, respectively, with a tender and soft texture (Martínez-Sánchez et al., 2012). The search for a better quality leaf with a longer shelf-life is a continuing process from preharvest to postharvest processing operations (Clarkson et al., 2003). Baby leaves are generally characterized as very perishable products with high respiration and water loss (Wang, 2003). In fact, water loss is a major cause of postharvest deterioration of leafy vegetables because it results not only in a direct quantitative loss of saleable weight, but also in deterioration in appearance (wilting and shrivelling) and textural quality (softening, flaccidity and loss of crispness) (Kader, 1992). Unfavourable postharvest conditions for baby leaves before minimal processing can affect the quality of the raw material and shorten the shelf life (Medina et al., 2012).

Temperature control is the most important factor in the handling of raw materials for the fresh-cut industry (IFPA and PMA, 1999). Delays between harvest and cooling should be avoided, especially during warm weather since water loss rates will be high (Cantwell and Kasmire, 2002). The process that removes the heat from the field immediately after harvest is called precooling (Brosnan and Sun, 2001). Reducing the temperature of

* Corresponding author. Tel.: +34 968 396 315; fax: +34 968 396 213.
E-mail address: migil@cebas.csic.es (M.I. Gil).

http://dx.doi.org/10.1016/j.postharvbio.2014.12.003
0925-5214/

fresh produce after harvest greatly reduces respiration rate, extends shelf-life and protects produce quality, while reducing volume losses by decreasing the rates of water loss and decay (Paull, 1999; Thompson et al., 2008; Kitinoja and Thompson, 2010). Shrivelling and the loss of fresh, glossy appearance are two of the most noticeable effects of cooling delays, particularly for leafy vegetables that lose water quickly and show visible symptoms at low levels of water loss (Thompson et al., 2001). Leafy greens including baby spinach are particularly prone to rapid dehydration.

The selection of cooling method is influenced by different factors such as the nature of product, the type of packaging used, the requirements of product flow and economic constraints (Brosnan and Sun, 2001). The principal methods of precooling highly perishable produce include: (i) room cooling, (ii) forced air cooling, (iii) hydro cooling, (iv) vacuum cooling and (v) water-spray vacuum cooling, with many variations within these techniques (Thompson et al., 2002). Some products may be cooled by any of these methods without suffering any loss in quality while others may be affected adversely depending on the type of cooling technique applied (Wang, 1993). In room cooling (i) cold air from the evaporator coils sweeps past the produce containers and slowly cools the product. Advantages of room cooling are; that produce can be cooled and stored in the same room without the need for transfer, its ease of design and operation, and there is no investment in equipment. However, room cooling has severe limitations because it is too slow for most commodities although cooling rates are variable (Thompson et al., 2002, 2008). In forced air cooling (ii), air forced through produce is used as the cooling medium, and it is more adaptable to a wide range of commodities than any other cooling method (Thompson, 1998). However, forced air coolers have a low efficiency due to high levels of heat input (Thompson and Chen, 1988). In hydro cooling (iii), cooling is accomplished by moving cold water around the produce with a shower system or by immersing the produce directly in cold water. Hydro cooling avoids water loss and may even add water to a slightly wilted commodity, as is often done with leafy green vegetables. However, in some leafy vegetables, water remaining on the surface tends to increase decay development (Brosnan and Sun, 2001). Vacuum cooling (iv) is based on rapid evaporation of part of the moisture of the product under vacuum, and it is one of the most rapid evaporative cooling techniques (Sun and Zheng, 2006). One disadvantage of vacuum cooling is that it causes weight loss in the produce being cooled due to removal of moisture (McDonald and Sun, 2000). Various methods have been proposed to compensate water loss, including pre-wetting product prior to cooling (Sun 1999), and water sprayers inside the chamber (Zheng and Sun, 2004; Thompson et al., 2008). Vacuum cooling has been widely applied as the best precooling system for whole lettuce heads (Sun and Brosnan, 1999; He et al., 2004). Some studies have investigated the influence of vacuum cooling in other vegetables including broccoli (Sun, 1999), spinach (Sun, 2000; Xie et al., 2013) and Chinese leaves (Sun, 2000). Overall results show that vacuum cooling is an effective and efficient cooling method for these products.

In the case of baby leaves, there is no detailed information about the best conditions for precooling the product after harvest before processing. Most of the information regarding this topic is part of the know-how of the technicians who hand and process these commodities. Nowadays, they are precooled following the general recommendations of leafy vegetables such as lettuce which include to begin and finish the cooling as rapidly as possible with precooling systems such as hydro cooling or vacuum cooling (Anon., 1994; Wright, 2004; Acedo, 2010). However, science-based information is limited. The objective of this study was to evaluate the effect of four precooling systems such as room cooling, forced air cooling, hydro cooling and vacuum cooling on the quality of minimally processed baby spinach. Quality parameters including sensory evaluation, colour and leaf water content, respiration rate as well as microbiological counts and cell damage, were evaluated. Trials were conducted at industrial facilities.

2. Materials and methods

2.1. Plant material

Spinach (*Spinacia oleracea* L.) was cultivated under commercial conditions in fields near Pulpí (Almería, Spain) by Primaflor S.L. Commercial varieties of baby spinach are usually specific to a short period of time and their commercial utilization rarely covers more than one season. For this reason two different spinach varieties were evaluated. Sowing was performed directly on elevated beds using a plant density of 700 plants m^{-2}. Plant material (60 kg) was harvested mechanically on 23rd January 2013 (winter variety) and on 24th April 2013 (spring variety). After harvest, leaves were transported to Primaflor facilities in Pulpí (Almería, Spain). The growing cycle was 56 and 36 d respectively for winter and spring variety, respectively.

2.2. Precooling, processing, packaging and storage conditions

Four precooling systems, room cooling (RC), forced air cooling (FAC), hydro cooling (HC) and vacuum cooling (VC), were evaluated in winter and spring seasons with winter and spring varieties, respectively. Spinach was precooled after 2 h from harvest at Primaflor facilities in perforated plastic boxes (0.5 × 0.36 × 0.31 m) under commercial conditions. Three boxes with 5 kg each were used for each precooling treatment. After harvest, the product temperature was 6 °C in January and 11 °C in April. Samples were precooled by the different precooling systems until the product reached a temperature of 3–5 °C. Temperatures of baby spinach were measured before and after cooling (Table 1) using a thermometer (TFA 30.103, TFA Dotsmann Gmbh & Co., Germany) with a probe located in the centre of the product.

Room cooling was conducted in a chamber of 45 × 20 × 7.5 m at 3 °C and 60% RH. Samples were precooled during 3 h in winter and 6 h in spring. Forced air cooling was carried out with an evaporative fan with a power of 1.1 kW and a humidifier panel. At sample level, air velocity was 7 km/h, air temperature was 3 °C and 95% RH. Samples were precooled by forced air cooling during 15 min in the winter and 30 min in the spring trial. The hydro cooling consisted of a shower with a water capacity of 400 m^3, at a water temperature of 3 °C and cycle time of 5 min. Vacuum cooling was carried out in a vacuum cooler with a capacity for 12 pallets, with a power of 500 kW and a working pressure of 9.1 mbar at an internal temperature of 2 °C. Before vacuum cooling, samples were showered with water and were precooled during 15 min in the winter and 30 min in the spring trial.

After precooling, baby spinach leaves were transported (150 km) under refrigerated conditions in polystyrene boxes to the CEBAS-CSIC laboratory (Murcia, Spain). Baby leaves were

Table 1
Temperatures (°C) of baby spinach before and after precooling using different cooling systems.

	Winter	Spring
Before cooling		
	5.9 ± 0.2	10.8 ± 0.3
After cooling		
Room cooling	4.1 ± 0.4	4.0 ± 0.9
Forced air cooling	4.0 ± 0.3	5.5 ± 0.4
Hydro cooling	4.4 ± 0.3	5.4 ± 0.5
Vacuum cooling	3.5 ± 0.2	3.0 ± 0.1

Values are the mean of 3 boxes ± standard deviation.