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Baby-leaf and multi-leaf of green and red lettuces are suitable raw materials for the fresh-cut industry

Ascensión Martínez-Sánchez[a], María C. Luna[a], María V. Selma[a], Juan A. Tudela[a], Jesús Abad[b], María I. Gil[a,*]

[a] Research Group on Quality, Safety and Bioactivity of Plant Foods, Food Science and Technology Department, CEBAS-CSIC, P.O. Box 164, E-30100 Espinardo, Murcia, Spain
[b] Zeta Seeds Research Station, P.O. Box 72, 04100 Níjar, Almería, Spain

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ABSTRACT

Consumer demand for softer leaves with variation in taste, shape and colours has encouraged the development of new lettuce products of baby-sized leaves. The objective of this study was the comparison of whole-head lettuce, as the most common raw material for fresh-cut, with baby-leaf and multi-leaf as the newest baby-sized lettuce leaves. Lettuces (*Lactuca sativa* L.) of the types Green Leaf, Red Leaf and Lollo Rosso were cultivated in the same field with different plant densities, under commercial conditions. Although baby-leaf was subjected to far less wound damage than the shredded lettuce from the whole-head, leaf age could play an important role in increasing respiration rate and determining postharvest quality. After 9–11 d of storage, minimally processed products from the three types of raw material showed good visual quality without differences among them. However, over the 12-d storage period, quality decreased to the limit of marketability mainly due to browning of the cut edge surface of the fresh-cut product from whole-heads and decay due to the soft tissue in the case of baby-leaves. Additionally, with the processing of whole-heads, the increase in cut-damage surfaces and availability of cell nutrients provided conditions that favoured the growth of lactic acid bacteria (LAB) and total coliforms compared to uncut surfaces of baby-sized leaves. The ratio between the oxidized and reduced forms of ascorbate (DHA/AA) increased 2–4 times after 9–11 d of storage. Furthermore, baby-sized leaves had higher phenolic contents than the shredded product from the whole-head which probably contributed to reaching a shelf-life of 11 d. In conclusion, the new green and red baby-sized leaves both at immature and mature stages provided high quality lettuce for the fresh-cut market, meeting specific requirements regarding visual quality, microbial load and high content of phytochemicals.

1. Introduction

Since the beginning of the fresh-cut produce industry, product development of new varieties of raw materials has been in constant evolution. Nowadays, innovation is still a fundamental factor to fulfil consumer expectations in terms of convenience, freshness, flavour, and quality (Floristán, 2009). Lettuce is one of the most important ready-to-use products and ranks highly both in production and economic value among vegetables. Although prepared salads continue to consist principally of iceberg lettuce, other types of lettuce, with attractive colours and shapes, combining the best quality characteristics from all varieties are used in salad mixes called "mesclun" in France or "spring mix" in the U.S. (Rijk Zwaan, 2009). As consumers are looking for softer textures, baby-sized leaves have been one of the most promising fresh-cut developments. The new baby-sized leaves using baby-leaf at an immature stage and multi-leaf at a mature stage have been developed recently as high quality lettuce varieties for the fresh-cut market. Some benefits of baby-sized lettuce when compared with whole-head lettuce include: (1) greater efficiency with higher percentage of usable product, (2) easier and faster processing, (3) more attractive presentation in packaging because of the 3-D structure, and (4) minimal oxidation due to smaller stem diameter. Likewise, one benefit of multi-leaf lettuce when compared with baby-leaf is firmer leaves which can confer longer shelf-life. However, comparison of the quality characteristics and shelf life of these products, once bagged, is still unknown.

It is generally accepted that the physical damage that occurs during preparation of whole-heads causes an increase in respiration rates, biochemical changes and microbial spoilage, which may result in degradation of colour, texture and flavour of the fresh-cut produce and development of browning during storage (Cantwell, 1996). In the case of baby-sized leaves, the product can be processed without any further preparation because the entire leaf is

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

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Table 1
Description of the sowing, transplanting, harvest and growing cycle as well as climatological data of sunshine, rainfall, radiation, net radiation and temperature during the growing period of green and red varieties of baby-leaf, multi-leaf and whole-head lettuces.

Raw material	Sowing date	Transplanting date	Harvest date	Growing cycle (days)	Mean sunshine (h/day)	Rainfall (mm)	Mean radiation ($w\,m^{-2}$)	Net radiation ($MJ\,m^{-2}$)	Mean temperature (°C)
Baby-leaf	12/12/2008	–	02/16/2009	66	7.0	24.2	121.7	3.0	8.5
Multi-leaf	11/07/2008	12/12/2008	02/10/2009	95	6.8	24.0	117.9	2.8	8.4
Whole-head	11/07/2008	12/12/2008	03/17/2009	130	7.4	79.0	141.4	4.2	9.1

Date: month/day/year.

harvested. Because the stem diameter is small, a lower wound-response can be expected, with less bruising and minimal oxidation when compared with the whole-heads. All these characteristics suggest a relatively longer storage potential of multi-leaf in terms of better colour, nutritional and microbiological qualities.

On the other hand, differences in the maturity stage between baby-leaf, as immature leaves, and multi-leaf, as mature leaves, can affect the shelf-life of the processed produce. Small leaves of kale have almost double the respiration rate of full size leaves when stored at different temperatures (Cantwell and Suslow, 2004). Higher respiration rates indicate a more active metabolism and usually a faster deterioration rate. Also higher respiration rate can result in more rapid loss of acids, sugars and other components that determine flavour quality and nutritional value (Cantwell and Suslow, 2002). However, the literature available regarding the effect of the maturity stage on the phytochemicals is not clear. In the case of spinach, some authors found that the intermediate maturity stage had a higher content of bioactive compounds (Pandjaitan et al., 2005) while other studies showed that the more mature stage showed a higher antioxidant content when compared with baby-sized stage (Zhao et al., 2007). In the case of lettuce, some authors reported that the maturity stage negatively affected the vitamin C content (Drews et al., 1997). Moreover, leaf age also affects microbial survival and proliferation. Brandl and Amundson (2008) observed that specific enteric pathogens could proliferate faster in the immature leaves than in the more mature ones.

Our hypothesis was that baby-sized leaves could be more appropriate as raw material for the fresh-cut industry, because of a lower degree of cutting which can decrease respiration rate and the adverse reactions of browning during storage. However, due to the tender texture of baby-leaf compared to multi-leaf, maintenance of excellent sensory properties, microbial quality and constituents responsible for pigmentations such as anthocyanins, may be difficult, particularly in the immature stage. Thus, within this study we aimed to increase knowledge of the influence of the raw material for the fresh-cut industry by focusing on the quality characteristics and shelf-life of the processed product. The objective was to understand the causes of quality loss in one of the most consumed ready-to-eat products, "baby-sized lettuces". Changes in sensory quality, physiological, microbial and nutritional properties were evaluated during the shelf-life of the processed product from green and red baby-leaf, multi-leaf and whole-head lettuces as raw materials for fresh-cut.

2. Materials and methods

2.1. Plant material and growing conditions

Lettuces (*Lactuca sativa* L.) of the types Green Leaf, Red Leaf and Lollo Rosso from Z-Seeds S.L. (Almería, Spain) were cultivated under commercial conditions in Pulpí (Almería, Spain) by Primaflor S.L. A randomised complete block design with three replicates or plots per variety and type of raw material was used. For baby-leaf, sowing was performed directly on beds using a plant density of 800 plants m^{-2} on 12 December 2008. The harvest time was determined on the total leaf length, between 5 and 9 cm including the blade and the petiole. The harvest was carried out mechanically on 16 February 2009 and 1.5 kg was sampled per plot with a total of 4.5 kg. For multi-leaf and whole heads, lettuce seeds were sown in a nursery greenhouse on 7 November 2008. Seedlings were transplanted in the field 35 d after with plant densities of 30 and 7 plants m^{-2} for multi-leaf and whole heads, respectively. Multi-leaf lettuces were harvested just before the initiation of plant heading on 10th February 2009 while whole heads were harvested when the heading was completed on 17th March 2009. For multi-leaf and whole heads, 15 lettuce heads per plot were manually harvested. The growing cycle for baby-leaf, multi-leaf and whole-heads was 66, 95 and 130 d, respectively (Table 1). Climatological data corresponding to the growing cycle in the open field is provided in Table 1. Both baby-leaf and multi-leaf were defined as baby-sized leaves, baby-leaf as an immature stage and multi-leaf as a mature stage.

After harvest, the leaves were placed in small boxes and directly transported (150 km) to the CEBAS-CSIC laboratory (Murcia, Spain) under refrigerated conditions and kept 24 h at 4 °C and 70% relative humidity (RH) in darkness. The next morning, samples were processed and different measurements such as leaf length, texture and dry matter, were taken before processing in 20 leaf or tissue portions, depending on the raw material.

2.2. Processing, packaging and storage conditions

Each type of raw material and genotype was independently processed in an isolated and cleaned minimal processing room at 4 °C. For baby-leaf, leaves with defects such as bruising or discoloration were hand-removed before washing, but no physical wounding was occasioned, except that of the harvesting operation. For multi-leaf, the lettuce core was hand removed 4 cm above the bottom and then the leaves were separated easily. For whole-heads, outer leaves were hand-removed to mimic the trimming in commercial harvesting operations and then heads were cut into 30 mm pieces using a sharp stainless steel knife. The rest of the process was the same for all leaf-sized lettuces. Samples were well mixed until homogeneous and then washed for 30 s in 100 mg mL^{-1} chlorine solution (NaOCl) adjusted to pH 6.5 with citric acid, drained for 30 s and then rinsed with tap water for 30 s. Excess water was removed by spinning for 1 min at 440 rpm in an automatic salad spinner (K-50, Kronen GmbH, Kehl am Rhein, Germany). Samples of 120 g were mechanically packed in a vertical packaging machine (Etna 280-X model, Ulma, Oñati, Spain) using a polypropylene (PP) film (Amcor Flexibles, Bristol, UK), with O_2 permeance of 2.63×10^{-12} mol s^{-1} m^{-2} Pa^{-1} and CO_2 permeance of 9.84^{-12} mol s^{-1} m^{-2} Pa^{-1} at 7 °C and 97% RH. Package size was 230 mm × 290 mm. Passive MAP was created by the respiration rate of the product and film permeability characteristics as packages were sealed under air conditions. Packages were stored in darkness for 3 d at 4 °C and then transferred to 7 °C for the rest of the storage.

Just after processing, some measurements were taken on the processed product such as dry mater content and texture. Dry matter content was determined by drying the samples in an oven at 65 °C until constant weight. Dry matter content was calculated as