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Growing season climates affect quality of fresh-cut lettuce

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ABSTRACT

The objective of this study was to investigate if different growing season climates influenced the quality of fresh-cut lettuce. Different cultivars and harvests of iceberg and romaine lettuce grown over 26 months were processed and stored for 11 d in active modified atmosphere (MA) and then transferred to air for 24 h at 7 °C. Pearson correlation coefficients were established between different climatic factors and subjective and objective parameters related to quality loss. Growing season mean temperature (GST) and growing cycle influenced the quality characteristics of fresh-cut lettuce but the correlations between GST and quality characteristics were always higher than for growing cycle in both types of lettuce, iceberg and romaine. Winter growing season caused low oxygen (O_2) and more significantly high carbon dioxide (CO_2) that reduced enzymatic browning although it conferred off-odors. Respiration rate was significantly influenced by GST but only in fresh-cut romaine. Interestingly, off-odors and fermentative metabolites such as ethanol and acetaldehyde were significantly reduced in those months of higher GST. However, cut edge browning was significantly promoted, indicated by the reduction in hue angle as GST increased. These results identified that the mean temperature during cultivation was the climate variable that contributed most to quality loss of fresh-cut lettuce. Due to the strong impact of growing season climate, some changes in raw material specifications, packaging design and days of shelf life are recommended in order to assure the quality of fresh-cut lettuce during the whole year.

1. Introduction

The main goal for growing lettuce for the fresh-cut industry is to produce over the whole year high quality raw material for processing (Rogers et al., 2006; Titley et al., 2007). Growers schedule different cultivars for different seasons in distant regions of contrasting altitudes to produce a continuous supply of high yield, good quality lettuce delivered to the processing plants. Different cultivars may need to be chosen depending on the growing period to synchronize well with the changes in climate because of the interaction between genotype and environment (Dufault et al., 2006). The information growers get from the seed companies is generally based on yield and other lettuce characteristics of the whole head with little reference to their suitability for fresh-cut.

Lettuce crops are exposed to considerable variations in environmental conditions during different growing seasons. Kumar et al. (2010) observed a low influence on yield and quality due to environmental conditions. However, when lettuce is exposed to supra optimal temperatures, physiological disorders such us tip burn, rib discoloration, ribbiness and premature bolting may occur (Jenni and Yan, 2009). In addition, if lettuce is produced in the optimal temperature range (7 – 24 °C), the crop takes between 70 and 100 days to market maturity while in warm and humid periods of long photoperiods lettuce matures in only 55-70 days. These differences in the growing period must influence the post cutting life.

The environmental conditions, including temperature, are often unmanageable in field production but have strong implications in crop quality (Weston and Barth, 1997). These authors described that as lettuce is a cool season crop it must be produced in areas with cool days and nights to achieve firm but mild-flavored heads. If the crop is exposed to high temperatures, bitter flavors can rapidly develop and the leaves become less tender (Peirce, 1987; Bunning et al., 2010). Hilton et al. (2009) reported that changes in environmental conditions such as cold or heat stress during growth influence the extent of post cutting discoloration to a greater extent than agronomic factors. In the case of growing

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season climate, several factors are determinant of lettuce quality such as growing season mean temperature (Dufault et al., 2009) and light quality and light intensity (Gruda, 2005). The influence of temperature and solar radiation on head weight demonstrated the sensitivity of the lettuce crop to environmental conditions (Wurr et al., 1992a). Exposure of high temperature and radiation has been shown to increase the production of phenolic compounds in green lettuce (Caldwell, 2003) and pigmented lettuce (Marín et al., 2015). Temperature serves as an indicator on the growth processes of the vegetable crop (Gruda, 2005) and it has been described as the major environmental factor affecting quality of vegetables (Workneh and Osthoff, 2010).

Hodges and Toivonen (2008) reviewed the impact of production, processing and postharvest stresses on quality attributes of fresh-cut fruits and vegetables. These authors described that the shelf life of the cut produce is almost invariably dependent upon the stress tolerance of the raw commodity to adverse environmental conditions and that produce which is stressed in preharvest stage will invariably have reduced postharvest quality. Lettuce appearance after cutting is followed by development of browning and off-odors as the two main causes of quality loss. Correlations between subjective quality and physicochemical attributes have been described for the quality evaluation of fresh-cut produce (Nunes, 2015). Hue angle and the content of fermentative metabolites such as ethanol and acetaldehyde have been proposed for the quality evaluation related to browning and off-odors, respectively of fresh-cut lettuce (Tudela et al., 2016).

There is limited literature describing the quality variables in response to varying season climates to understand differences in the shelf life after cutting. Processors know that the quality of the fresh-cut lettuce changes over the year but there are no data to support quality differences caused by different growing season climates. Therefore, the objective of this study was to determine the effect of diverse growing season climates on quality of fresh-cut lettuce. To accomplish this objective, data were collected from different cultivars and harvests for iceberg (n = 80) and romaine (n = 77) grown in 4 different and distant regions that covered the yearly production in Spain. Subjective and objective quality characteristics as affected by growing season temperature (GST) regimes were evaluated.

2. Materials and methods

2.1. Plant material

Experiments were carried out over 26 consecutive months on commercial farms that supplied one of the most important fresh-cut processors in Spain. Different regions covered the whole yearly production including winter in Murcia (38° latitude, 41–350 m altitude), spring and fall in Albacete (39° latitude, 692 m altitude) and Navarra (42° latitude, 285 m altitude) and summer in Soria (42° latitude, 857 m altitude) (Table 1). The type of soil changed depending on the area but in general it was sandy loam. For all cultivars, seedlings were grown for about 4 weeks in greenhouses and then planted and cultivated following similar cultural practices for drip irrigation, fertilizers and pest management. Cultivars of iceberg and romaine lettuce represented the most common ones used in Spain for each season with a total number of 20 for iceberg and 9 for romaine with at least two harvests per cultivar (Table 1). The names of the cultivars are not mentioned because for the purpose of this study they are not relevant and also for the confidential agreements with growers and processor.

Differences between planting dates and harvest dates are considered as the growing cycle, which varied from 48 days at the end of summer to 120 days for the mid-winter harvest. Climatic data during the growing cycle were obtained from the nearby field climatic stations of Torre Pacheco and Lorca for Murcia, La Gineta for Albacete, San Esteban de Gormaz for Soria, and Cadreita y Funes for Navarra growing area. Mean temperatures during the growing cycle were determined by averaging the daily mean temperature from transplanting date to harvest date that were equivalent to the days of growing period (Dufault et al., 2009). For each season, mean growing period, harvest week and the number of cultivars studied are indicated in Table 1.

Lettuce heads (30 heads per cultivar) were harvested and transported to the CEBAS-CSIC laboratory (Murcia, Spain). Heads were stored at 4° C in darkness until processing the following day. Harvest maturity indicators were evaluated in 10 heads per cultivar including head weight and dry matter. Head weight of iceberg varied between 400 and 840 g while for romaine varied from 300 to 700 g (Gil et al., 2012). Dry matter (DM) was measured in 3 samples of fresh-cut lettuce per cultivar and harvest. Samples of 50 g were dried for 48 h in a forced air oven at 65 °C until constant weight.

Table 1
Seasons, growing periods, harvest weeks and cultivars of iceberg and romaine lettuce studied.

Lettuce types	Seasons	Growing periods (days)	Harvest weeks	Cultivars
Iceberg	Winter	92	46–17	1–13
	Spring	67	18–24	4, 13–17
	Summer	55	25–39	4, 8, 15, 17–20
	Autumn	52	40–45	14, 15, 20
Romaine	Winter	92	46–18	1–7
	Spring	59	19–25	8
	Summer	52	26–39	8, 9
	Autumn	52	40–45	1, 4, 8, 9

2.2. Fresh-cut processing, packaging and storage conditions

Lettuce heads were processed at 4 °C in sanitary conditions following good manufacturing practices. Heads were manually shredded (3 cm segments) using a stainless steel knife, washed for 60 s in chlorine (100 mg L^{-1} NaOCl) at pH 6.5 adjusted with citric acid, rinsed for 30 s in tap water and then dried for 1 min using an automatic salad spinner (K-50, Kronen GmbH, Kehl am Rhein, Germany). Fresh-cut iceberg (300 g) and romaine (175 g) were mechanically packed (Etna 380 model, Ulma Packaging, Oñati, Spain) with an orientated polypropylene (OPP) flexible film with O_2 and CO_2 permeabilities of 1.913E^{-16} mol m m^{-2} s^{-1} Pa^{-1} and 5.740E^{-16} mol m m^{-2} s^{-1} Pa^{-1} at 23 °C and 0% RH. Bag dimensions were 230 mm x 280 mm. Active MA was generated by injection of nitrogen gas (N_2) before sealing to achieve an initial concentration of approximately 0.5–1.5 kPa O_2. Packages were stored at 7 °C in active MA for 11 d and then transferred for 24 h to air. These storage conditions were already standardized for the screening of lettuce cultivars for fresh-cut (Tudela et al., 2016). Three to five packages from each cultivar and harvest were assessed every sampling day to determine changes in quality over time.

2.3. Respiration rate and headspace analysis

Headspace gas composition (O_2 and CO_2) was monitored daily in 3–5 individual bags per cultivar and harvest. Two repetitions of 0.25 mL of headspace gas were taken per bag. The respiration rate was calculated from the CO_2 accumulated in the active MA packages at 10% O_2 using the methodology described by Lee et al. (1996), where RR_{CO2} was the rate of CO_2 production (mmoL kg^{-1} s^{-1}), considering the CO_2 permeability coefficients of the film, the film area, film thickness and product weight. Respiration rate and