Manejo cosecha y tecnología postcosecha

Artículo de investigación científica y tecnológica

Changes in the physico-chemical properties of four lettuce (*Lactuca sativa* L.) varieties during storage

Cambios en las propiedades fisicoquímicas de cuatro variedades de lechuga (*Lactuca sativa* L.) durante el almacenamiento

Mudanças nas propriedades fisicoquímicas de quatro variedades de alface (*Lactuca sativa* L.) durante o armazenamento

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Abstract

Lettuce, a popularly consumed leafy vegetable, is well known for its health and nutritional value. Thus, the current study focused on the qualitative changes of four lettuce varieties, namely Alpha, Parris Island, Graziella and Lollo Rossa, stored at 5.5 °C and 90 % RH for 12 days. The analyzed parameters were water content, total soluble solids (TSS), titrable acidity (TA), vitamin C, total phenols, polyphenoloxidase (PPO), color and texture. Under storage conditions, the studied varieties exhibited different rates of water loss. TSS was found to increase until day 8 of storage, which is also when TA differences were observed. The Graziella variety showed the highest vitamin C levels. Total phenol content decreased significantly during the 12 days of storage. No significant PPO activity changes were found, except for those of the Lollo Rossa variety. Biplot analysis allowed observing not only positive and negative correlations between coordinates L*, a* and b*, but also the separavtion of the green lettuce varieties from the red one, together with color variations depending on leaf position. Although textural changes were recorded at the end of the study, foliage quality was not altered. In short, the studied parameters, which contribute to lettuce direct consumption properties, can be said to be variety-dependent and better preserved under refrigeration.

Key words: Biochemistry, *Lactuca sativa*, Leaf vegetables, Plant nutrition, Post-harvest

Resumen

La lechuga es una hortaliza de amplio consumo popular, por sus beneficios para la salud y la nutrición. Se estudiaron los cambios en calidad de cuatro variedades (Alpha, Parris Island, Graziella y Lollo Rossa) almacenadas durante 12 días a 5,5 °C y 90 % HR. Se determinaron contenido de agua, sólidos solubles totales (SST), acidez titulable (AT), vitamina C, fenoles totales, polifenol oxidasa (PFO), color y textura. Las variedades de lechuga tuvieron tasas diferentes de pérdida de agua y modificaciones en los SST y la AT. La variedad Graziella tuvo el más alto nivel de vitamina C. El contenido de fenoles totales se redujo significativamente en el día 12 de almacenamiento. No se observaron alteraciones en la actividad de la PFO excepto en Lollo Rossa. El análisis Biplot mostró correlaciones positivas y negativas de las coordenadas L*, a* y b*, con lo cual se observó una clara definición de dos grupos de lechuga: verde y roja. Se hizo evidente la modificación en la tonalidad del color de acuerdo con la posición de las hojas. Se registraron cambios en la textura al final del almacenamiento, que no alteraron la calidad del follaje. Si bien los parámetros evaluados varían según la variedad, la refrigeración contribuye a mantener las propiedades del vegetal para el consumo directo.

Palabras clave: bioquímica, *Lactuca sativa*, hortalizas de hoja, nutrición de las plantas, tecnología postcosecha

Resumo

A alface é uma hortaliça de amplo consumo popular por seus benefícios para a saúde e para a nutrição. Foram estudadas as mudanças em qualidade de quatro variedades (Alpha, Parris Island, Graziella e Lollo Rossa) armazenadas durante 12 dias a 5,5 °C e 90 % HR. Foram determinados conteúdo de água, sólidos solúveis totais (SST), acidez titulável (AT), vitamina C, fenólicos totais, polifenoloxidase (PPO), cor e textura. As variedades de alface tiveram taxas diferentes de perda de água e modificações nos SST e na AT. A variedade Graziella teve o mais alto nível de vitamina C. O conteúdo de fenólicos totais se reduziu significativamente no 12º dia de armazenamento. Não foram observadas alterações na atividade da PFO exceto em Lollo Rossa. A análise Biplot mostrou correlações positivas e negativas das coordenadas L*, a* e b*, com isso foi observada uma clara definição de dois grupos de alface: verde e vermelha. Fez-se evidente a modificação na tonalidade da cor de acordo com a posição das folhas. Foram registradas mudanças na textura ao final do armazenamento que não alteraram a qualidade da folhagem. Embora os parâmetros avaliados variam segundo a variedade, a refrigeração contribui para manter as propriedades do vegetal para o consumo direto.

Palavras chave: bioquímica, *Lactuca sativa*, hortaliça de folha, nutrição vegetal, tecnologia pós-colheita

Introduction

Vegetables are considered to be a healthy, pleasant, necessary and important human food source. Often marketed fresh, the world consumption trend of these products is currently increasing. An outstanding place is held by those which, corresponding to constitutive parts of the plant and having low energetic content, are traditionally consumed in salads or cooked as part of secondary dishes or salty aperitifs (Combariza 2013). Provided that five out of seven Colombians (71.9 %) between the ages of 5 and 64 do not consume vegetables on a daily basis (especially in the central region) (ICBF 2010), the demand for these products in Colombia can be said to be at a critical point. In direct connection with this, *per capita* consumption is only 45.75 g/day, a figure that is far below the daily recommendation for fruits and vegetables (400-500 g/day) (WHO 2003). This is, in turn, associated to the nutritional condition of the Colombian population, among which there is serious prevalence of anemia and deficiencies of essential micro-nutrients such as Ca, I, Fe, Zn, folic acid and vitamins A and C (Neufeld et al. 2010).

Lettuce, *Lactuca sativa* L. (Asteraceae) is one of the most widely employed vegetables for food preparation purposes. It supplies water, polyphenols, carotenoids, fiber, Ca, Fe, K and antioxidants such as vitamins A, C and E (Serafini et al. 2002; Nicolle et al. 2004; Guerrero and Rojano 2010). Among the different types of lettuce, the most common ones are Romaine, Iceberg and Looseleaf. Yet, they are all sensitive to damage caused during cultivation, harvest or transportation, and to attacks by microorganisms that affect their quality during distribution, processing or storage. In most cases, both damage and microbial attacks result from the mechanical and physiological fragility of the product (Pereyra et al. 2005; Martínez et al. 2008; Serrato et al. 2011).

The value of vegetables depends on their quality, which is a broad concept including external appearance, nutritional value and content of healthy compounds (Cosetta 2014). Resulting from the chemical composition of the product, organoleptic and nutritional quality determines the sensorial characteristics that attract the consumer such as color, aroma, taste and texture. The nutritional value of the product results from its contribution of nutrients that are essential for health, such as proteins, carbohydrates, vitamins and minerals, all of which have a protective effect against diseases (López 2003).

Several physiological variables are associated to the quality of lettuce. Water content determines the crispness and juiciness of the leaves (Kader and Barrett 2004); taste depends on the content and combination of sugars, organic acids and phenolic compounds (Mello et al. 2003; Menezes et al. 2005); and vitamin C, although present in low amounts, preserves the nutritional quality of the product when it is consumed fresh (Aćamović-Djoković et al. 2011). For their part, phenolic compounds have been associated to lettuce shelf life increase (Martínez-Sánchez et al. 2012); color has to do with its antioxidant properties (Pérez et al. 2014); and texture, which corresponds to the physical characteristics perceived at the moment of chewing, is related to material deformation, disintegration and flow under force application (Alcántara 2009).

Many countries have implemented campaigns to promote the consumption of fruits and vegetables as a disease prevention strategy (Restrepo et al. 2013), the most recent one alluding to 7-13 daily portions (Ungar et al. 2013). In Colombia, public and private entities supported by international organisms are promoting changes in food consumption habits through the daily incorporation of five fruit or vegetable products in the population diet (Asohofrucol 2007).

The present study evaluated the post-harvest behavior of four lettuce cultivars with the aim of contributing useful information to the consolidation of a new food culture that favors the nutritional status of vegetable consumers.

Materials and methods

Location

A lettuce crop was grown in the municipality of Rionegro, department of Antioquia, Colombia, at the facilities of the Colombian Corporation for Agricultural Research (Corpoica), La Selva Research Center, (06°07′49″ North, 75°24′49″ West; 2,090 m asl; 17 °C temperature; 1,917 mm precipitation; 78 % relative humidity (RH); 1,726 hours/year solar radiation; and 1,202 mm evapotranspiration; all yearly average data). The ecological formation corresponds to a Lower Montane Rain Forest (LM-rf). Instrumental procedure was carried out in the Quality Analysis Laboratory of Corpoica, La Selva Research Station.

Biological material

Varieties Graziella (Romaine), Lollo Rossa (leaf), Paris Island (Romaine), and Alpha (butterhead) were planted in 1.6 m wide by 4.4 m long plots. Planting distances were 0.40 m between furrows and 0.30 m between plants, resulting in a population of 83,333 plants/ha.

Experimental procedure

The treatments corresponded to the four evaluated varieties, which were grown under a randomized complete block design with five repetitions. Lettuce standard management practices were applied along the production cycle until the plants reached their maximum size and before the appearance of any senescent leaves. The plants were harvested manually from 7:00 to 8:00 am, and then transported to the laboratory, where they were washed. After removal of the damaged and dirty external leaves, the harvested plants were stored at 5.5 °C and 90 % RH. Foliage samples were obtained every four days until day 12, the moment of harvest corresponding to day zero. Statistical analyses were carried out in SAS 8 (SAS Institute Inc. 2005). Differences between means were calculated through a Tukey's test at a 95 % confidence level. Whenever the Variety x Time interaction was found to be significant, the data were plotted to observe contrasts among groups of means. Color coordinates were subjected to principal components analysis in order to observe grouping patterns.

Analytical procedures

Water content (%) was determined according to the method by AOAC (2000).

Total soluble solids (°Brix) were determined according to the Colombian technical norm 4624 (Icontec 1999). For such purpose, a Milton RoyTM refractometer (Michigan City, IN, USA) was employed, the values thus obtained being adjusted to temperature.

Titratable acidity (% ascorbic acid) measurement was carried out under the potentiometric titration method (AOAC 2005) with some modifications (0.5 mL of lettuce juice diluted in 25 mL of Milli-Q water).

Vitamin C (mg/100 g) was determined through Tillman's method (AOAC 1980). For such purpose, 1.5 g of lettuce leaf juice extracted by maceration were put into a 100 mL flask and homogenized with oxalic acid (0.5 %). Then, a 5 mL aliquot was titrated with a Tillman solution (0.01 %) until obtaining a clearly visible rose color persisting for at least 15 s. A standard ascorbic acid curve was taken as reference.

Total phenols (mg gallic acid/g) (Madison, WI, USA) were determined by the Folin-Denis method (AOAC 1997). For 10 min, 1.5 mL of juice extracted by maceration of the leaves were centrifuged at 4,000 rpm and 4 °C in a MSE Harrier 18/80™ centrifuge, London, UK. Then, a 25 µL aliquot was mixed with 125 µL of the Folin Ciocalteu reactive and 450 µL of type 1 water. After 6 min of incubation, 400 µL of 7.2 % sodium carbonate were added, and the solution was kept in the dark for 60 min. Next, absorbance was read at 760 nm in a Thermo Scientific Genesys 10™ spectrophotometer, Madison, WI, USA. The values thus obtained were contrasted with a gallic acid standard curve.

Polyphenoloxidase (UAE/min/mL) was determined according to the method by Ortega-García et al. (2005). A plant tissue sample was powdered with liquid nitrogen and washed thrice with cold acetone (4 °C). Then, it was resuspended in a 0.1 M sodium phosphate buffer (pH 6.2), with 0.3 mg/mL of trypsin. After filtering, the resulting solution was centrifuged at 20,000 rpm and a temperature of 4 °C in a MSE Harrier 18/80™ (London, UK) centrifuge for 20 min. Every 30 s, absorbance changes in the supernatant were measured at 395 nm in a Thermo Scientific Genesys 10™ spectrophotometer (Madison, WI, USA) for a period of 30 min. Different catechol concentrations were employed as substrate.

Color assessment followed methodology by León et al. (2007), making use of a Chroma Meter CR-400 Konica Minolta Sensing Inc.TM colorimeter (Tokyo, Japan), which recorded coordinates L*, a* and b*. The reference illuminant was standard daylight. Triplicate measurements (on the upper, right and left portions of the leaf lamina) were taken on the adaxial side of both an external and an internal leaf.

Texture (N) was analyzed according to methodology by Fernández (2012), employing a Stable Micro Systems Ltd TA.TXplus™ texture analyzer (Godalming, UK), equipped with a Warner-Bratzler HDP/BSK™ blade (Ulm-Einsingen, Germany). Pre-test speed was 0.5 mm/s, whereas test and post-test speeds were respectively 2.0 mm/s and 5 mm/s. Advance distance was 10 mm. Compression force was evaluated by measuring peak effort applied on leaves taken at different foliage depths.

Results and discussion

Water content. The values of this parameter ranged between 92.25 and 95 %, in agreement with those reported by Montesdeoca (2009) for varieties Lollo Rossa, Green Salad Bowl and Red Salad Bowl; and by Suárez (2013) for Capitata variety. Figure 1 shows a reduction in foliage water content since harvest. The differences among varieties probably indicate unequal cellular water storage capacities, in turn resulting from disparity in the development of the tissues (Esparza-Rivera et al. 2006; Agüero et al. 2008). The ANAVA applied to the water content reduction data revealed a significant Time x Variety interaction. Variety Alpha stands out for its higher water content, probably resulting from its butterhead morphology, which prevents water loss. This is in contrast with the low water retention properties of loose leaf varieties, which, on the other hand, exhibit better appearance and texture (Holcroft 2015; Kozuki et al. 2015).

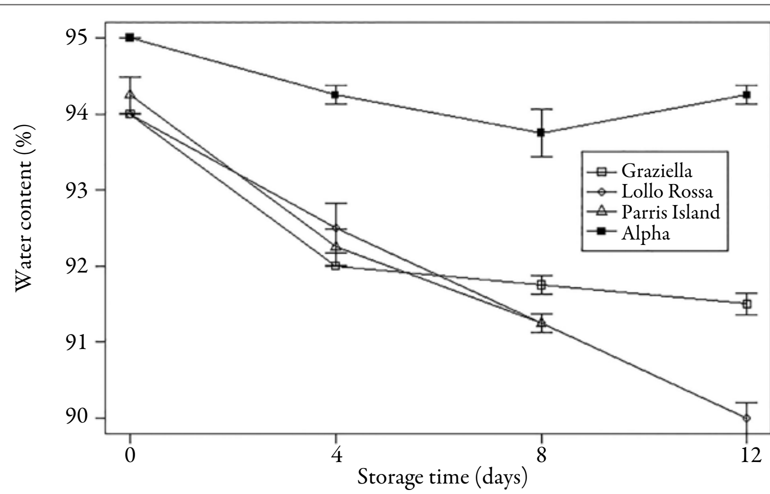

Figure 1. Postharvest changes in water content of four lettuce varieties during storage at 5.5 °C and 90 % R.H. Vertical bars represent SE (n = 4).
Source: Own elaboration

Total soluble solids (TSS). At harvest, soluble solids content in all the studied varieties ranged from 3.2 % to 4.6 % (figure 2), as also reported by Ozgen and Sekerci (2011), Silva et al. (2011) and Bahri et al. (2012). The green varieties showed higher TSS content than the red one, in agreement with Ozgen and Sekerci (2011). In general, this is a potentially important feature since taste —which, depending on the product is a more or less significant quality attribute— is partially formed by soluble solids. In lettuce, taste is mainly formed by two factors: bitterness, which is determined by organic acids, lipids and phenols (Mello et al. 2003; Menezes et al. 2005; Martínez 2010); and sweetness, which is directly associated to fructose, glucose, sucrose and fiber, in that order (21 % of total glucids). However, lettuce being poor in sugars and rich in phenolic compounds, its TSS content is not considered to be an important quality indicator, although it was directly correlated with the preservation of a pleasant taste over time (Varoquaux et al. 1996; Martínez 2010). In the current case, TSS level increase during storage might be due to degradation of polysaccharides into simple sugars, thereby causing a rise in TSS. This quality attribute, which contributed to good taste preservation (Esparza-Rivera et al. 2013), is in contrast with a former analysis carried out by Delaquis et al. (2000), who found that fresh lettuce taste diminishes during storage.

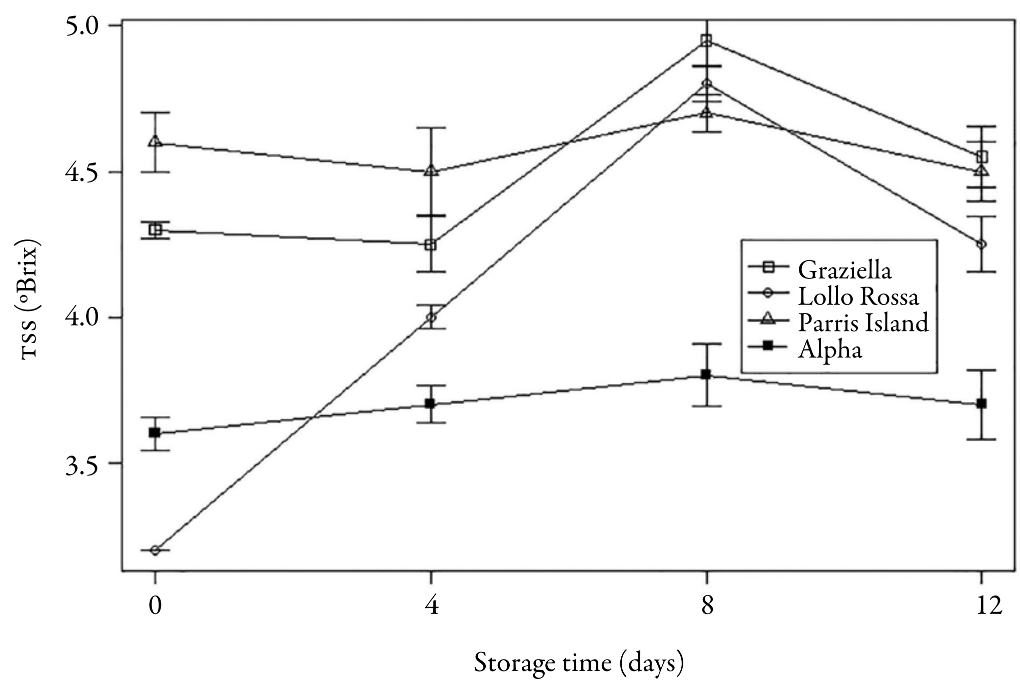

Figure 2. Postharvest changes in total soluble solids of four lettuce varieties during storage at 5.5 °C and 90 % R.H. Vertical bars represent SE (n = 4).
Source: Own elaboration

Titratable acidity. Figure 3 shows changes in this variable for the studied varieties along storage time. At harvest, varieties Alpha and Parris Island registered the lowest acidity counts (0.17 %), whereas the values of varieties Lollo Rossa and Graziella came close to 0.28 %. These differences, which were found to be significant, remained steady all along the study. The observed titratable acidity, which was lower than that reported by Torres (2013), but higher than that measured by Suárez (2013), is attributable to genetic differences and to the genotype x environment interaction. Lettuce acidity is a function of its organic acid content (citric, malic and tartaric acids, as stated by Deza (2013); and Torres (2013), which tends to decrease during storage because these compounds are a substrate for respiration. Yet, the current results indicate an increase in titratable acidity along storage time, due to the moderate respiration rate that features refrigerated lettuce (6-10 mL CO_2/kg/h at 5.5 °C). This makes the studied varieties less susceptible to attacks by fungi or bacteria, thus extending their shelf life (Pitt and Rocking 2009). Hence, it is no surprise that lettuce exhibits better quality when refrigerated, as compared to that kept at room temperature.

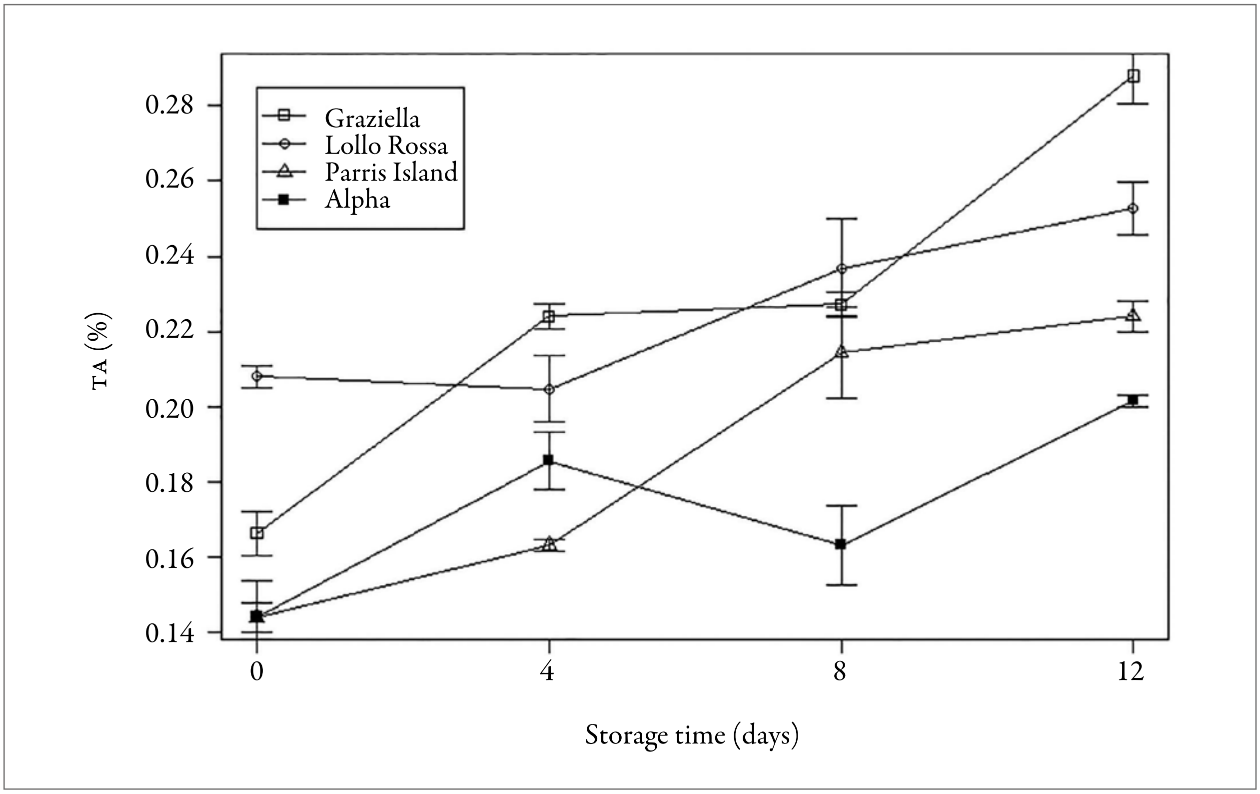

Figure 3. Postharvest changes in titratable acidity of four lettuce varieties during storage at 5.5 °C and 90 % R.H. Vertical bars represent SE (n = 4).
Source: Own elaboration

Vitamin C. At harvest, the highest vitamin C levels corresponded to variety Alpha (18.39 mg/100 g), followed by Parris Island (19.29 mg/100 g), Graziella (18.39 mg/100 g) and Lollo Rossa (15.21 mg/100 g) (figure 4). These values, which are higher than those obtained by Nicolle et al. (2004) and Llorach et al. (2008), indicate that the content of vitamin C depends on lettuce type (Silva et al. 2011) and is higher in the green varieties as compared to the red one (Lollo Rossa) (Aćamović-Djoković et al. 2011). However, at the end of the trial, variety Graziella showed the highest vitamin C level (30.22 % of citric acid), while the other varieties exhibited a drop. It is generally considered that if this vitamin is retained during storage, other nutrients are likely to have the same fate, which preserves the parameters associated to freshness and nutritional quality at high standards (Spinardi et al. 2010). Significant differences were found in comparing varieties Lollo Rossa, Graziella and Parris Island to Alpha on day 8; and Lollo Rossa, Parris Island and Alpha to Graziella on day 12, as also reported by Petříková and Pokluda (2003).

Vitamin C levels are influenced by weather (temperature, relative humidity and solar radiation), crop management practices and postharvest management, as well as the variety in question (Koudela and Petříková 2008). Although lettuce is not rich in vitamin C, the fact that it is usually consumed fresh allows the complete assimilation of this nutrient and its utilization in several biological processes that —due to the thermolabile nature of this vitamin— would be affected if the product was cooked as other foods (Lee and Kader 2000; Aćamović-Djoković et al. 2011).

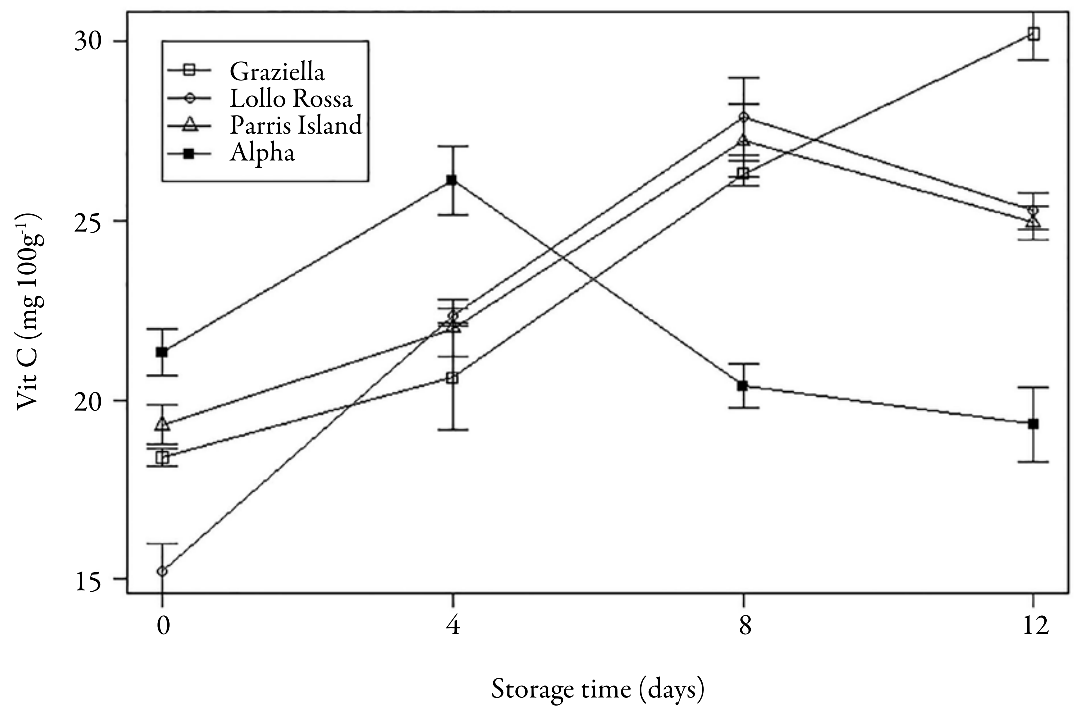

Figure 4. Postharvest changes in vitamin C content of four lettuce varieties during storage at 5.5 °C and 90 % R.H. Vertical bars represent SE (n = 4).
Source: Own elaboration

Total phenols. At harvest, the highest content of these compounds was measured in variety Lollo Rossa, followed by Parris Island, Graziella and Alpha (figure 5). These differences were found to be significant for varieties Lollo Rossa and Parris Island on days 0, 8 and 12. However, this trend was not consistent with substrate concentration over time, in agreement with former reports by Tavarini et al. (2007), who observed an increment, and by Zhang and Hamauzu (2003), who recorded a decrement. Phenols are secondary metabolites originated in two routes, namely those of shikimic acid and polyacetates. In lettuce, the most important phenols are diosmetin, luteolin and chlorogenic and caffeic acids (Parente et al. 2013), due to their potential benefits for human health and intimate relation with tissue browning during storage (Spinardi et al. 2010). The higher content of phenols in the pigmented variety Lollo Rossa when compared to the green varieties (Parris Island, Graziella and Alpha) coincides with the results obtained by Llorach et al. (2008), Martínez-Sánchez et al. (2012) and Pérez (2014). This property is associated to an elevated antioxidant activity and, therefore, to a higher nutritional value. In addition, the elevated anthocyanin levels of this lettuce type facilitate a better presentation of the product when it is used in the design of minimally processed salads.

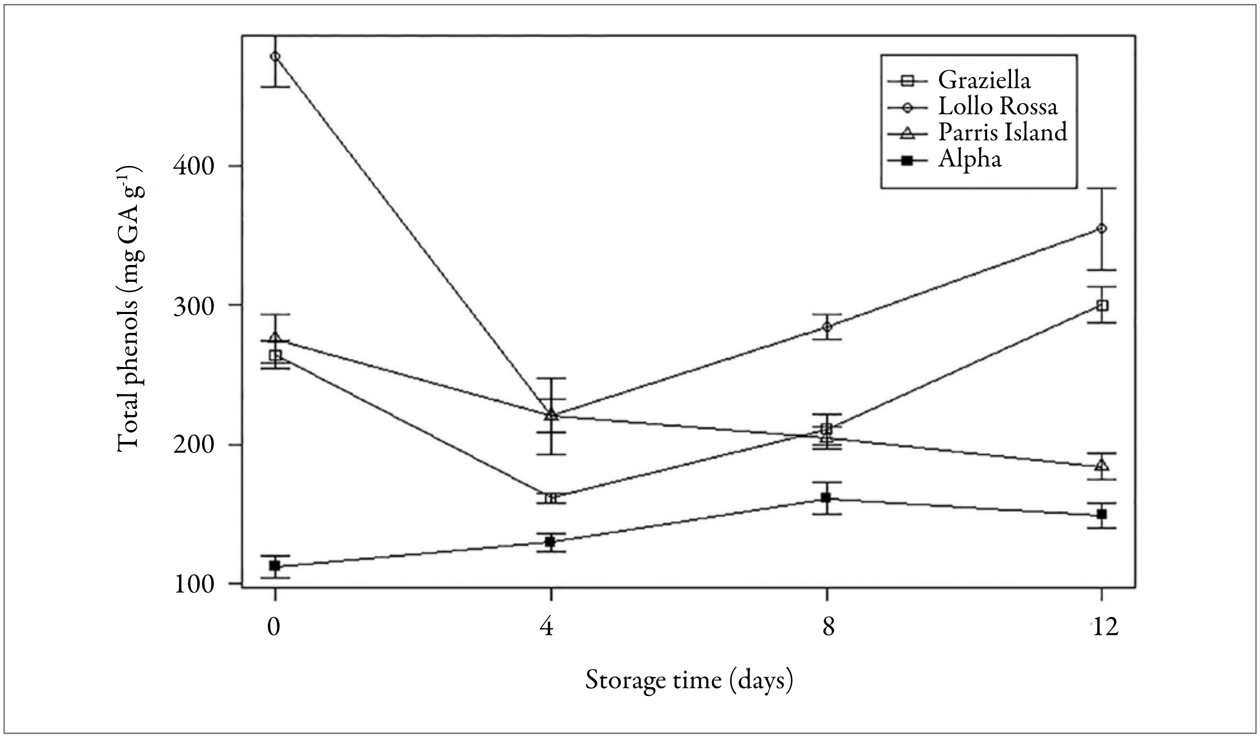

Figure 5. Postharvest changes in total phenols of four lettuce varieties during storage at 5.5 °C and 90 % R.H. Vertical bars represent SE (n = 4).
Source: Own elaboration

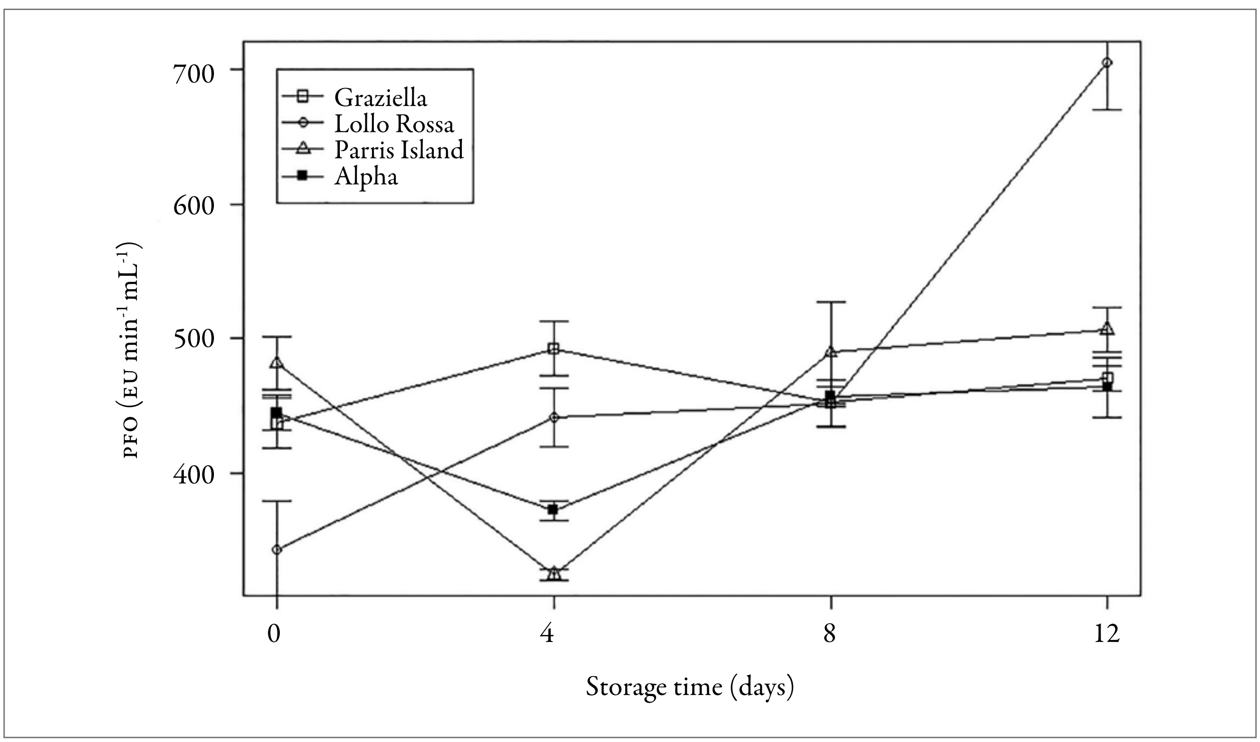

Figure 6. Postharvest changes in polyphenoloxidase of four lettuce varieties during storage at 5.5 °C and 90 % R.H. Vertical bars represent SE (n = 4).
Source: Own elaboration

Polyphenoloxidase (PPO). The activity of this enzyme showed a slight tendency toward steadiness along the study, without significant differences among varieties, except for an increase recorded in Lollo Rossa at the end of the trial (figure 6). This is probably due to increased sensitivity of this variety to the reduced levels of vitamin C recorded at that time (Landi et al. 2013). These results are in agreement with those found by Tavarini et al. (2007) in refrigerating varieties Verpia and Lollo Rossa. These authors observed that the optimum temperature for the activity of this enzyme is species specific, ranging from 15 to 56 °C depending on the substrate employed for enzymatic activity determination (Złotek and Gawlik 2015). Phylogenetically speaking, PPO is a broadly distributed enzyme among all living tissues. It catalyzes the reactions leading to tissue browning, especially during post-harvest, when the products are subjected to stress conditions resulting from management, storage and processing (Neves et al. 2009; Pace et al. 2014). The current data indicate that refrigeration has a positive influence on the preservation of the sensorial attributes of lettuce such as appearance, taste and texture, because low temperature reduces the deleterious effect of PPO (Esparza-Rivera et al. 2013).

Color. By applying the L* a* b* color space methodology to the varieties under analysis, no significant differences were detected for coordinates L* and b* along the study, whereas coordinate a* (red/green) did show significant differences (table 1). This is consistent with the fact that, during storage, vegetables containing chlorophyll undergo color losses due to external factors such as light, temperature, humidity, oxygen or ethylene; and to internal factors like the activity of the enzyme dechelatase, as well as oxidative routes in which peroxidase might be involved (Yamauchi and Watada 1991; Shioi et al. 1996).

Table 1. Postharvest changes of color parameters in four lettuce varieties during storage at 5.5 °C and 90 % R.H.

S. T.[1]	L*	a*	b*
0	50.75 a[2]	-13.74 ab	24.10 a
4	52.93 a	-12.96 a	23.74 a
8	51.41 a	-14.17 b	25.10 a
12	52.60 a	-13.93 ab	25.10 a

[1] Storage time (days)
[2] Means followed by the same letter in a given column do not differ significantly at 5 % according to the Tukey test.
Source: Own elaboration

Leaf color across the studied varieties is shown in figure 7. A strong correlation can be observed between the measurements of coordinate a*. The latter correlate negatively with coordinates b* and L*, which are, in turn, positively correlated to one another. Two groups can be clearly observed. On the right side of the plot is a cluster identified with open circles, exhibiting elevated values of coordinate a* (lower green and higher red intensities), coupled to low values of coordinates b* (bluish tones) and L* (opaque tones). All this corresponds to the variety Lollo Rossa. The other cluster, located on the left side of the plot, includes those varieties with low values of coordinate a* (green) and high values of coordinates b* (yellow) and L* (luminosity). Within this group, variety Graziella (crosses), which is as bright as variety Alpha (squares), exhibits the lowest values for coordinate a*, and the largest ones for coordinates b* and L*. Within this same group, varieties Parris Island (closed circles) and Alpha (squares) are slightly shifted towards the red-bluish zone, differing between them in luminosity, with higher values of the coordinate L* in Alfa. Such expectable grouping is explained in the red variety by the presence of anthocyanins (Llorach 2008), and in the green varieties by their differences in form and size, which affect sunlight penetration and, therefore, the synthesis of photodependent metabolites and nitrogen assimilation (López et al. 2014).

Table 2 presents variations in the color of the studied leaves with respect to their position on the plant, mainly resulting from anthocyanin accumulation and chlorophyll degradation. Each coordinate varies significantly with leaf position. The values of L* and b* diminish outwardly. Elevated a* values were detected in the leaves of Lollo Rossa (red), due to their elevated anthocyanin levels. In turn, the external leaves of Parris Island, Graziella and Alpha (green) exhibited low values of a* resulting from elevated chlorophyll contents. Color changes are a function of leaf maturity, external leaves being more mature than internal ones. The former not only have higher pigment accumulation capacity, but also more abundant synthesis of secondary metabolites, which results from their being more directly exposed to the environment (Ozgen and Sekerci 2011). Contrastingly, and considering leaf position from a nutritional standpoint, Siomos et al. (2002) state that external leaves are not as wholesome as internal ones.

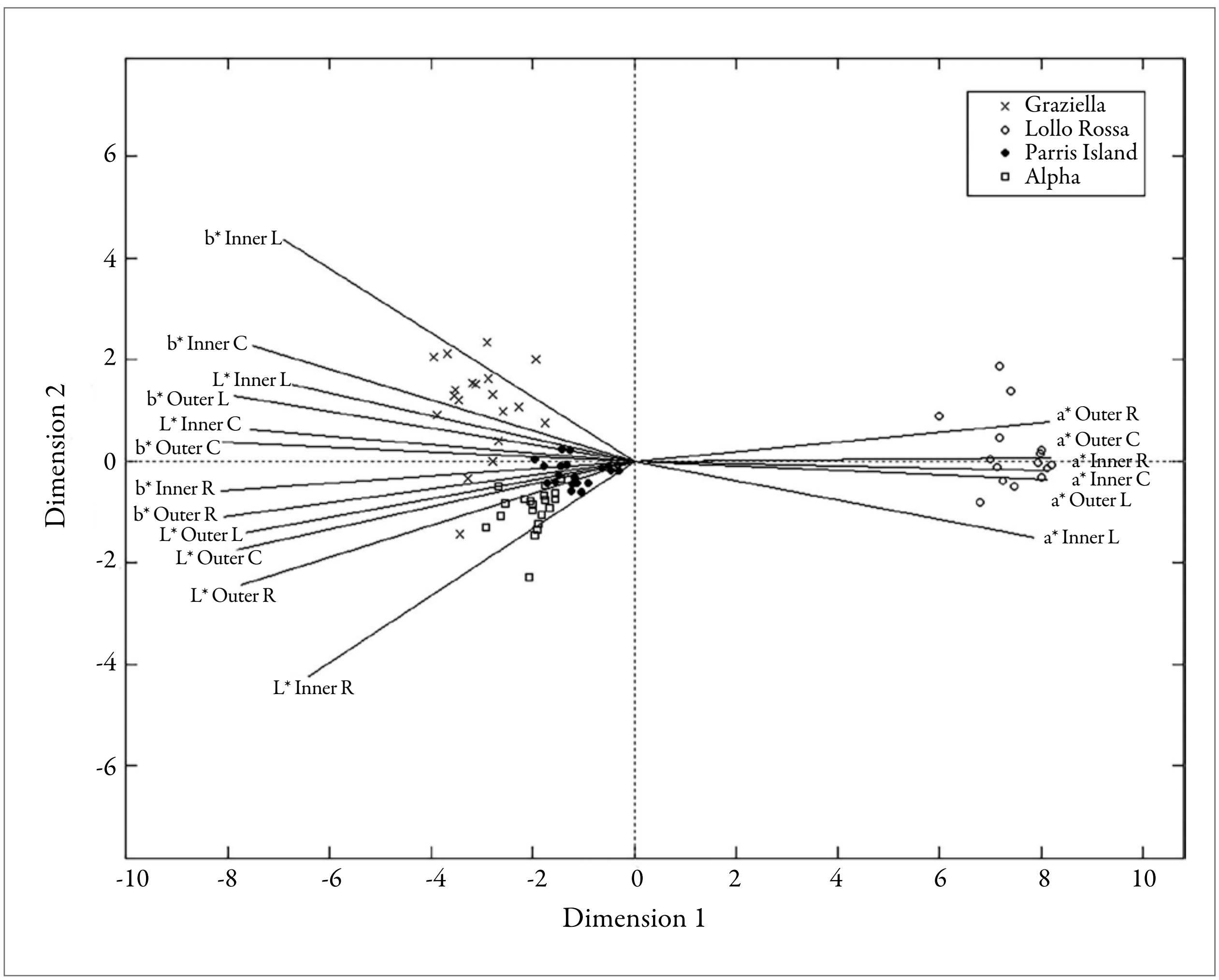

Figure 7. PCA Biplot indicating the existence of two different groups of four lettuce varieties. Dots represent leaf position. L = left; M = middle; R = right.
Source: Own elaboration

Table 2. Lettuce color parameters as affected by variety and leaf position during storage at 5.5 °C and 90 % R.H.

Source	Lollo Rossa			Parris Island			Graziella			Alpha		
	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
Internal leaf	25.72a[1]	3.48a	4.16a	43.72a	-14.53a	23.46a	44.09a	-15.8a	26.63a	46.25a	-3.53a	22.73a
External leaf	26.38a	6.00a	4.22a	50.52a	-14.94a	23.48a	54.34a	-17.42b	36.61a	57.51b	-13.58a	26.29b

[1] Means followed by the same letter in a given column do not differ significantly at 5 % according to the Tukey test.
Source: Own elaboration

Texture. Highly significant differences were observed for the Variety x Time interaction. On days 4 and 8, the fracture force in varieties Alpha and Parris Island decreased, after which it was found to increase. In varieties Graziella and Lollo Rossa, this parameter underwent a constant increment all along the study (figure 8). This was consistent with the visual appearance of the product and the sensation obtained by chewing its leaves, which were evaluated since harvest and until day 12, revealing turgor and crispness changes. These results differ from those obtained by He et al. (2004) and Selma et al. (2012), who recorded lower texture values for varieties Alpha and Lollo Rossa. The differences observed in the current study might be interpreted as a favorable variation in elasticity due to cell turgor rather than a positive evolution of this physical characteristic. On the other hand, it must be considered that the instrumental measuring of texture in lettuce is made difficult by tissue variability. In effect, the position of oblique, parallel and perpendicular vascular strands with respect to the parallel plates of the texture analyzer directly affect the measurements (Toole et al. 2000; Martin-Diana et al. 2006).

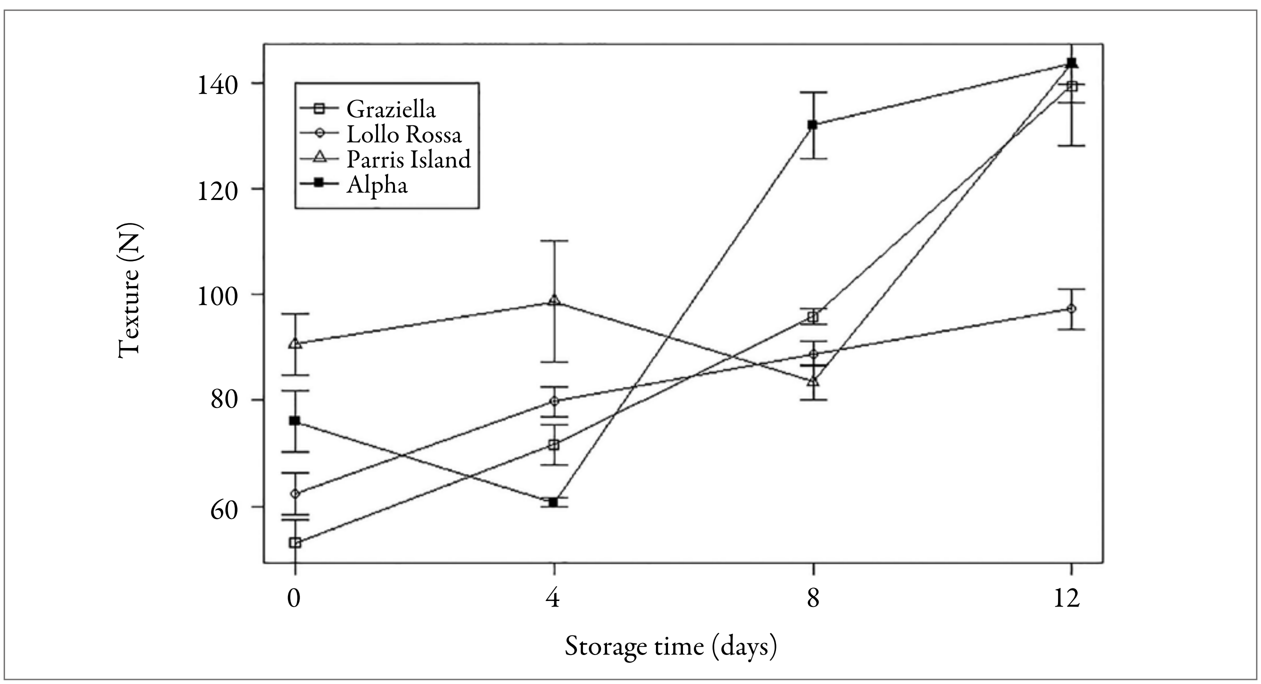

Figure 8. Postharvest changes in texture of four lettuce varieties during storage at 5.5 °C and 90 % R.H. Vertical bars represent SE (n = 4).
Source: Own elaboration

These results indicate that the sensorial characteristics and content of secondary metabolites in the lettuce change among varieties. Such information could be useful to consumers as it may help them make decisions when preparing healthy salads.

Conclusions

The differences expressed by the studied lettuce varieties can be attributed to different phenotypic expressions of their characteristic genetic diversity.

Lettuce water content was found to depend on the way the leaves are distributed around the main stem, the butterhead variety Alpha standing out for its elevated scores. Total soluble solids content was found to be higher in the green foliage varieties than in the red one; this particular feature contributed to good taste preservation in the former varieties (Graziella, Parris Island and Alpha). Significant titratable acidity differences were found between lettuce types. This parameter was observed to increase toward the end of the study. Although the recorded levels of vitamin C confirm lettuce as a very discrete source of this nutrient, the way the product is usually consumed makes it potentially beneficial for the consumer. Total phenol contents were higher in variety Lollo Rossa, which confers it relatively better antioxidant properties. The low PPO activity recorded for the varieties Graziella, Parris Island and Alpha favors the maintenance of fresh-cut lettuce physicochemical quality when it is used for the preparation of ready-to-eat foods. Biplot analysis of CIELAB chromaticity parameters was sensitive enough to discriminate the varieties by their color, as well as the tone differences of the leaves according to their position on the plant. Textural changes observed during storage did not alter the quality of the studied genotypes.

Lettuce growers, horticultural specialists, consumers and other actors of the production-distribution-sales chain are potential beneficiaries of the current results.

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Disclaimer

The authors declare that they do not have any conflicts of interest.

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