Nutritional and sensory evaluation of ready-to-eat salads during shelf life

KEYWORDS: Ready-to-eat salad, total phenolics, antioxidant capacity, ascorbic acid, sensory quality, principal component analysis.

Abstract
The evolution of the antioxidant and sensory properties of six commercially available ready-to-eat salads, rocket, iceberg lettuce, baby lettuce, lamb’s lettuce, curly endive and radicchio, was studied throughout the shelf life. Both the storage under modified atmosphere and in unsealed pouch in a domestic refrigerator were considered and compared. Ascorbic acid, total phenolics content and antioxidant capacity were chosen as the most representative nutritional parameters for this purpose. The data obtained were analyzed by Principal Component Analysis (PCA). Radicchio, lamb’s lettuce and rocket showed an initial higher content of the quality parameters studied and demonstrated a better resistance to air exposure than the other salads, being ascorbic acid the most affected parameter. Modified atmosphere packaging demonstrated to be a very useful and reliable technology to extend nutritional and sensory properties during the shelf life period for all the vegetables studied.

INTRODUCTION
Fruits and vegetables are rich sources of different various bioactive compounds with antioxidant activities, such as vitamins A, C and E and phenolic compounds, which recent studies have shown to be good contributors to the total antioxidant capacity of the foods that contain them (1). Antioxidant components provide protection against harmful free radicals, and have been strongly associated with reduced risk of chronic diseases (2). These facts have led the World Health Organization (WHO) and many health authorities in various countries, to recommend the intake of 400 g of vegetables and fruits, equivalent to 5 portions per day (3). In particular, recent studies have shown the health effects of lettuce and rocket in preventing cardiovascular diseases and cancer in rats and humans, the healthy properties are attributed to a large supply of antioxidant compounds mainly vitamin C and total phenolics as well as the fibre content (4). Ready-to-eat vegetables typically involve peeling, slicing, dicing or shredding prior to packaging and storage. Wounding and other minimal processing procedures can cause physiological changes, including ethylene production, increase in respiration rate, membrane deterioration, water loss, increased rate of vitamin loss, rapid softening, shrinkage, loss of chlorophyll, loss of acidity, increase in sweetness, formation of flavour volatiles, enzymatic browning, lipolysis and lipid oxidation and a shorter storage life (5). Most such changes may impact adversely on the antioxidant status of these products. Decrease in the antioxidant activity after processing was reported for fresh-cut spinach (6) and fresh-cut mandarin (7). Otherwise, wounding caused an increase in antioxidant activity of Iceberg and Romaine lettuce (8) and in total phenols in peppers (9). Levels of ascorbic acid, carotenoids or phenolics can reflect the variations in antioxidant capacity of fruit and vegetables (10, 11). The processing procedures also affect the sensory quality of ready-to-eat salads that is the most important factor for consumer purchasing choice and therefore its changes over shelf life must be taken into account for a complete evaluation (12). Modified atmosphere packaging (MAP) is a preservation technique already in use by the fresh-cut industry. Low levels of O₂ and high levels of CO₂ reduce the produce respiration rate, with the benefit of delaying senescence, thus extending the storage life of the fresh produce (12). The aim of this work was to evaluate the quality changes of popularly consumed ready-to-eat salads during domestic shelf life, by the examination of three of the most interesting functional parameters for this kind of fresh-cut vegetables: antioxidant activity, phenolics and ascorbic acid content. Six vegetable types were considered, in order to assess also different storage behaviours related to the specie of origin. The results of the chemical analysis were compared to those from the sensory evaluation.

MATERIALS AND METHODS
Samples
Six fresh vegetables ready-to-eat salads were examined: rocket (Eruca sativa Miller.), iceberg lettuce (Lactuca sativa L. var. capitata), lamb’s lettuce (Valerianella olitoria L.), curly endive (Cichorium endivia var. crispa), radicchio (Cichorium intybus L. var. “chioggia tondo”), baby lettuce (Lactuca sativa L. var. saladbowl). The salads were purchased in...
modified atmosphere packaging, evaluating color, texture and overall acceptability (including absence of off-flavours) as quality attributes, by comparing results at the beginning and at the end of storage period. The scale is a numerical representation of a subjective evaluation that considers the severity of the symptom (16); rating from 1 (excellent fresh), 2 (very fresh), 3 (fresh), 4 (acceptable), 5 (just acceptable), 6 (just unacceptable), 7 (unacceptable), 8 (deteriorated), 9 (completely deteriorated) and 10 (extremely deteriorated). The cut-off score was fixed at 5. The sample was considered as unacceptable when a mean score above five was reached.

**Statistical analysis**

One-way analysis of variance (ANOVA) was performed for each ready-to-eat salad to obtain a statistical assessment of the evolution of the physicochemical parameters during storage. Means were separated by Tuckey’s test at p≤ 0.05 and at p≤ 0.01 significance, using the Statistical Analysis System (SAS Ver. 9.0). Correlation analysis was performed and the Pearson correlation coefficient was calculated. Principal component analysis (PCA), was applied in order to highlight a natural grouping of samples depending on their different antioxidant capacity and antioxidants content in relation to the different salad types, and to visualize the high dimensional data with respect to the influence of storage on the parameters studied. All the computations were performed using V-PARVUS (17).

**RESULTS AND DISCUSSION**

**Nutritional properties at the beginning of ready-to-eat salads shelf life**

Changes of antioxidant capacity for the six ready-to-eat salads studied, rocket, iceberg lettuce, baby lettuce, radicchio, lamb’s lettuce and curly endive are reported in...
The antioxidant activity of the six ready-to-eat salads during their shelf life has been assessed by two different assays, measuring the scavenging activity of methanol extracts with different free radicals, DPPH and ABTS.

The ranking of antioxidant capacity of individual vegetables samples was comparable for the two methods. At T0, the DPPH assay antioxidant activity values of radicchio and lamb’s lettuce and of rocket and curly endive were similar (p>0.05) (Table 1). Radicchio showed a much higher antioxidant capacity in accordance to literature data for red varieties of salads (p<0.01), due to the high presence of anthocyanins (18).

Evolution during storage

The evolution of the antioxidant capacity during storage was quite similar between the two assays (ABTS and DPPH) for all the salads (p>0.05), indicating that all the antioxidant compounds were equally affected both in air and in modified atmosphere packaging. Looking at DPPH variation from T0 to TF, the variety most affected by storage was iceberg (59%, p < 0.05) followed by baby lettuce (51%, p<0.01) curly endive (45%, p<0.01), lamb’s lettuce (21%, p<0.01), rocket (20%, p<0.05) and radicchio (13%, p<0.01). This ranking reflects quite well the content at T0, demonstrating that poorer initial quality will result in a shorter preservation.

The decrease of phenolics during shelf life in unsealed pouch in domestic conservation was evident in all the vegetables considered. The decline was more rapid in baby lettuce, where the phenolics content at T1 is 50% T0 (p<0.01), and at T2 is 30% T0 (p<0.01). Also curly endive and iceberg lettuce had a loss of 10% from T0 to T1 (p<0.05), while radicchio, rocket and lamb’s lettuce succeeded in maintaining the phenolics content at T1 till T2 (p<0.05), probably due to a synergistic and protective effect of the higher content in antioxidants and ascorbic acid. At the end of the shelf life period (TF), all the vegetables showed a significant decay that was near 70% for baby lettuce, 50% for curly endive, 30% for lamb’s lettuce and 15% for radicchio and rocket. On the contrary, the vegetables maintained under modified atmosphere packaging showed a phenolics content at the end of the shelf life period (TFC) not significantly different of that at T1 for rocket, lamb’s lettuce and curly endive (p>0.05) and that at T2 for the remaining samples.

Table 1. Change of the antioxidant capacity of different salad types during storage. Values are means ± Standard Deviation (n=18).

<table>
<thead>
<tr>
<th>Sample</th>
<th>T</th>
<th>DPPH (%)</th>
<th>ABTS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rocket</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T0</td>
<td>72.10 ± 3.12 A</td>
<td>36.33 ± 3.53 A</td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>66.67 ± 3.48 B</td>
<td>35.61 ± 3.31 A</td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>62.49 ± 4.09 B</td>
<td>33.47 ± 3.57 A</td>
<td></td>
</tr>
<tr>
<td>TF</td>
<td>57.73 ± 2.80 C</td>
<td>28.22 ± 2.05 B</td>
<td></td>
</tr>
<tr>
<td>TFC</td>
<td>64.24 ± 3.03 b</td>
<td>33.55 ± 5.29 A</td>
<td></td>
</tr>
<tr>
<td><strong>Iceberg</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T0</td>
<td>11.25 ± 1.69 a</td>
<td>10.25 ± 2.14 A</td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>10.19 ± 1.81 a</td>
<td>9.24 ± 1.14 b</td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>7.26 ± 1.48 b</td>
<td>6.43 ± 0.94 c</td>
<td></td>
</tr>
<tr>
<td>TF</td>
<td>4.60 ± 1.74 c</td>
<td>4.91 ± 0.56 d</td>
<td></td>
</tr>
<tr>
<td>TFC</td>
<td>7.38 ± 0.99 b</td>
<td>5.69 ± 0.83 c</td>
<td></td>
</tr>
<tr>
<td><strong>Lamb’s Lettuce</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T0</td>
<td>52.89 ± 3.95 a</td>
<td>31.86 ± 2.14 A</td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>54.41 ± 5.46 a</td>
<td>26.95 ± 2.11 B</td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>52.00 ± 3.23 a</td>
<td>21.91 ± 1.99 C</td>
<td></td>
</tr>
<tr>
<td>TF</td>
<td>25.73 ± 3.46 b</td>
<td>17.37 ± 2.66 D</td>
<td></td>
</tr>
<tr>
<td>TFC</td>
<td>36.40 ± 3.54 c</td>
<td>22.83 ± 2.49 B</td>
<td></td>
</tr>
<tr>
<td><strong>Radicchio</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T0</td>
<td>89.38 ± 2.79 A</td>
<td>88.28 ± 2.79 A</td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>85.71 ± 2.98 A</td>
<td>83.09 ± 2.72 A</td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>80.20 ± 2.46 B</td>
<td>81.41 ± 2.16 C</td>
<td></td>
</tr>
<tr>
<td>TF</td>
<td>71.00 ± 1.80 C</td>
<td>71.40 ± 1.68 C</td>
<td></td>
</tr>
<tr>
<td>TFC</td>
<td>81.1 ± 2.03 B</td>
<td>83.11 ± 2.31 A</td>
<td></td>
</tr>
<tr>
<td><strong>Curly Endive</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T0</td>
<td>72.94 ± 2.55 A</td>
<td>73.94 ± 2.55 A</td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>67.46 ± 2.11 B</td>
<td>67.84 ± 2.45 B</td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>60.47 ± 1.98 c</td>
<td>61.06 ± 1.66 C</td>
<td></td>
</tr>
<tr>
<td>TF</td>
<td>40.23 ± 2.69 d</td>
<td>39.21 ± 3.24 D</td>
<td></td>
</tr>
<tr>
<td>TFC</td>
<td>69.19 ± 2.82 B</td>
<td>69.02 ± 2.08 B</td>
<td></td>
</tr>
</tbody>
</table>

Values in the same column for each salad type having different letters are significantly different: p<0.01, small letters, p<0.05, capital letters.

Inhibition percentages of the two free radicals are quite similar for all the species except for rocket and baby lettuce, whose values for the ABTS assay are almost the 50% those from DPPH assay. These results suggest the presence of different kind of antioxidants, more active in DPPH free radical scavenging, that depends mainly on the number of hydroxyl groups present in molecules and on their electro donating ability, or the presence of interfering substances (19).

The phenols content of plants depends both qualitatively and quantitatively on variety, with red leafed-vegetables showing a higher content than green leafed varieties (20). These literature data are hereby confirmed (Figure 1 B), radicchio is the richest in phenols with double than rocket, baby lettuce and lamb’s lettuce content, and twenty-fold in comparison with iceberg lettuce. Baby lettuce and lamb’s lettuce show a similar content in phenols (p>0.05).

Results for ascorbic acid content in the samples analyzed are described in Figure 1A. At T0 ascorbic acid levels ranged between 56.7 (rocket) to 4.3 (curly endive) mg/100 g fresh weight. Remarkable also lamb’s lettuce with 17.00 mg/100 g fresh weight. After ANOVA test baby lettuce and radicchio, curly endive and iceberg lettuce showed a similar ascorbic acid content (p>0.05). These results highlight rocket as a good source of vitamin C, useful to reach by one only portion the recommended daily intake suggested by FAO (between 25 and 70 mg per day). (21). The ascorbic acid contents are in the range of previously reported for minimally processed vegetables (18, 22).
respectively. Figure 2 shows the loading (in blue) and score plot and well substantiates that the first component is mainly related to the antioxidant capacity assays and to phenolics results whereas the second component is mainly related to ascorbic acid. The score plot of the first two components, allows for the characterization of the salad variety according to the first and the second component. The samples were well separated according to their variety with no overlapping, and the vegetable groups are spread along the first component, except the group of rocket samples that is characterized by ascorbic acid. Therefore, PCA results confirm the preliminary evidences of the previous section, rocket has the highest content in ascorbic acid and this parameter can differentiate very well this vegetable variety from the others, radicchio had the highest content in phenolics and antioxidant capacity followed by rocket, baby and lamb’s lettuce, curly endive and iceberg lettuce. The interesting result coming from this PCA is that the samples are spread along the principal components in order of storage time. In particular, the sample at T0 of each salad has always the highest score on the component that differentiates the respective salad type, followed by the T1, T2 and TF samples, in decreasing order. TFC and T2 scores are quite close for all the salad types except for curly endive and baby lettuce whose TFC score are nearer to T1 and in the middle between T2 and TF, respectively.

Evaluation of sensory quality
The sensory quality was assessed to compare the main visual quality attributes for the consumer purchasing choice with the functional parameters studied and their respective evolution during the shelf life of the vegetables (Table 2). The judges evaluations during storage showed good correlations with changes of tested chemical parameters (r > 0.77, p < 0.05).
In particular, salads with a bigger decay in functional parameters, iceberg, baby lettuce and curly endive were judged unacceptable at the end of the under air storage period for all the visual properties tested. The most critical property was the texture and subsequent the general appearance, especially when stored unsealed. Another problem occurring during storage was the leaves browning that was more evident in shredded salads, such as iceberg, curly endive and radicchio, and led to high scores at T2. The salads in sealed bags had scores at the shelf life end period (TFC) comparable to those of T2, so modified atmosphere packaging preserves the vegetables slowing the natural visual quality decay until four days.
The agreement between the sensory-based spoilage and the decay in functional properties in all the salads studied might be interesting in promoting the idea of fruit and vegetables freshness associated to healthiness in consumer perception of ready-to-eat salads.

Chemometric evaluation
Principal component analysis (PCA) was used as unsupervised pattern recognition technique to visualize the data set. After autoscaling, two significant components were identified giving account for 64.6% and 26.5% of the total variance, respectively. Figure 2 shows the loading (in blue) and score plot and well substantiates that the first component is mainly related to the antioxidant capacity assays and to phenolics results whereas the second component is mainly related to ascorbic acid. The score plot of the first two components, allows for the characterization of the salad variety according to the first and the second component. The samples were well separated according to their variety with no overlapping, and the vegetable groups are spread along the first component, except the group of rocket samples that is characterized by ascorbic acid. Therefore, PCA results confirm the preliminary evidences of the previous section, rocket has the highest content in ascorbic acid and this parameter can differentiate very well this vegetable variety from the others, radicchio had the highest content in phenolics and antioxidant capacity followed by rocket, baby and lamb’s lettuce, curly endive and iceberg lettuce. The interesting result coming from this PCA is that the samples are spread along the principal components in order of storage time. In particular, the sample at T0 of each salad has always the highest score on the component that differentiates the respective salad type, followed by the T1, T2 and TF samples, in decreasing order. TFC and T2 scores are quite close for all the salad types except for curly endive and baby lettuce whose TFC score are nearer to T1 and in the middle between T2 and TF, respectively.
To evaluate the behaviour of vegetables during the different stages of storage, a second data matrix was built containing for each salad the percentage change of each parameter between T0 and the different storage times calculated by the formula (a), and between the values at expiration date when stored under modified atmosphere packaging (TFC) and in air (TF) by the formula (b):

\[
x_{Ve}(\%) = \frac{X_{Tm} - X_{T0}}{X_{T0}} \times 100
\]

\[
x_{VV}(\%) = \frac{X_{TFC} - X_{TF}}{X_{TF}} \times 100
\]

Where:

\(XV\) = Parameter Change; \(DV\) = antioxidant capacity by DPPH assay; \(AV\) = antioxidant capacity by ABTS assay; \(VV\) = ascorbic acid content; \(PV\) = Total phenolics content.

\(n\) = percentage change code: 1 = T0 vs T1; 2 = T0 vs T2; 3 = T0 vs TF; 4 = T0 vs TFC

\(Tm\) = storage time: T1, T2, TF, TFC.

Therefore, as an example, DV1 was the percentage change of the antioxidant capacity by DPPH assay between T1 and T0, DV2 between T2 and T0, DV3 between TF and T0, DV4 between TFC and T0 and DV5 between TFC and TF.

The PCA on this data matrix is shown in Figure 3. The first two components explained 73% of the variability. Principal component 1 was responsible for 56% while component 2 for 17%.

The first principal component (PC1) allowed to differentiate salads with a high change of quality parameters during storage (baby lettuce, curly endive and iceberg), from those that showed a better resistance (rocket, radicchio and lamb’s lettuce), interestingly, the latter group gathers the same salads that in the previous PCA graph were located in the right part of the graph, that with higher content in quality parameters. This result highlights the possibility of a protective and synergistic effect of antioxidant compounds.

The second component (PC2) divided the antioxidant capacity assays, in the upper right quadrant of the chart, from phenolics and ascorbic acid in the lower. In particular, the parameters most affected by air storage in baby lettuce were phenolics and ascorbic acid, noticeable the decrease of phenolics in the first two days after purchasing (PV1) and during shelf life period in MAP (PV4).

Iceberg and curly endive groups showed an overlapping zone that suggests a similar behaviour of the two species during storage, with the antioxidant capacity parameters showing the biggest decay. Furthermore, iceberg showed the greatest variability among samples that are spread in a large area of the PCA graph.

Regarding the difference between the end of shelf life considered for the open (TF) and the closed (TFC) bag, the corresponding loadings (designated with XV5) are very close, indicating that all the quality parameters considered are equally protected by MAP during shelf life. The ready-to-eat salads that show the greatest loss of nutrients when stored in air are iceberg lettuce and curly endive, with phenolics and ascorbic acid being the most affected. These results can be explained both by the initial minor content of these parameters, peculiar of the two vegetables, and by the cutting operations they underwent during processing where the presence of oxygen encourage the degradation of ascorbic acid and phenolics (24, 25). The case of radicchio can confirm this observation, despite being packaged as a cut vegetable, it maintains the functional parameters almost intact throughout the storage, probably due to the protective action of its high content in antioxidants. The results of our study support those reported by Perez Lopez et al., 2014. This research group monitored the decay kinetic of DPPH in relation to hydrophilic extracts from differently coloured lettuce cultivars and correlated the data with their relative antioxidant composition. They concluded that different decay rates were in relation with the presence or the absence of some antioxidants identified as slow-, intermediate-, and fast-rate antioxidants in the differently coloured lettuce cultivars (26).

**CONCLUSIONS**

In the present study the evolution of nutritional and sensory attributes of six varieties of ready-to-eat salads has been evaluated. The results suggest that the maintenance of functional quality of ready-to-eat salads under air storage is salad type-dependent, with an important role of the vegetable technology to extend functional and sensory quality during the shelf life period for all ready-to-eat salads. The functional quality behaviour was in accordance with the results of the sensorial evaluation, which is the most important aspect for consumer acceptability.

The quality parameters tested well characterized the ready-to-eat salad types and their behaviour during storage. Principal Component analysis well highlighted different grouping of the different salads varieties in relation to their different initial content in the antioxidant compounds.
parameters studied and their behaviour during shelf life. Among the vegetables studied, radicchio, lamb’s lettuce and rocket, showed high content in functional quality parameters that was maintained throughout the shelf life period even in domestic storage, such as to be considered “naturally functional foods” for high content in ascorbic acid in rocket and polyphenols in radicchio. Iceberg and curly endive showed a faster decay, probably due to the cutting operations they undergo during processing. Modified atmosphere packaging demonstrated to be a very useful and reliable technology to extend functional and sensory quality during the shelf life period for all ready-to-eat salads.

REFERENCES