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Influence of film and modified atmosphere on sensory quality of roasted apple cv. Reineta

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Abstract

The aim of this study was to determine the influence of film type and modified atmosphere on the sensory quality of roasted apple cv. Reineta. Roasted apples were packaged using two different films, LORE 90 COOK and CN 300, under two different modified atmosphere conditions, Extendapak 1® (100% N_2) and Extendapak 47® (7.0% CO_2 2.5% O_2 90.5% N_2). The Packaged apples were stored for 210 days at 3°C. Sensory analyses were performed every 14 days until the end of the storage period. Each sample was made up of 178 fruit for each type of packaging and for each storage time. No significant differences were found between the newly elaborated and the stored roasted apples according to the difference test until the 84th day of storage. No significant differences were found in the visual attributes of the apples, except for colour, neither between types of packaging nor between storage times. Significant differences were found in olfactory-gustatory attributes, odour intensity, sweet taste and alcoholic taste between type of packaging whereas significant differences were found between storage times for all olfactory-gustatory attributes. Juiciness was the only textural attribute that was significantly different between type of packaging and between storage times. When the film was less permeable of the film, the better the original properties of roasted apple cv. Reineta were kept better. There were significant differences between modified atmospheres, so Extendapak 1® was more appropriate than Extendapak 47® to keep the original characteristics of roasted apple cv. Reineta for a longer time.

Additional key words: modified atmosphere packaging; sensory acceptability; sensory analysis; shelf life; sous vide.

Resumen

Influencia del tipo de envase y del tipo de atmósfera modificada en la calidad sensorial de la manzana Reineta asada

El propósito del estudio fue el de analizar la influencia del tipo de material de envasado y el tipo de atmósfera utilizada para almacenar manzana cv. Reineta asada del Bierzo. Para ello se utilizaron dos tipos de materiales de envasado LORE 90 COOK y CN 300 y dos atmósferas de envasado diferentes denominadas Extendapak 1® (100% N_2) y Extendapak 47® (7.0% CO_2 2.5% O_2 90.5% N_2). Se almacenaron durante un periodo de 210 días a 3°C. Se realizaron análisis sensoriales cada 14 días. Cada muestra estaba formada por 178 frutas por cada tipo de envasado y para cada tiempo de almacenamiento. No se encontraron diferencias significativas en la prueba triangular entre manzanas recién elaboradas y manzanas almacenadas hasta los 84 días. En los atributos visuales valorados en el análisis descriptivo solo se encontraron diferencias significativas para el color tanto entre los tipos de envasado como a lo largo de la conservación. Para los atributos olfativos-gustativos se encontraron diferencias entre tipos de envasado para la intensidad de olor, sabor dulce y sabor alcohólico y para todos los atributos durante el tiempo de envasado. De los atributos de textura solamente presentó diferencias la jugosidad tanto en el tipo de envasado como a lo largo de la conservación. La manzana cv. Reineta asada y almacenada a 3°C conservó mejor sus propiedades iniciales cuanto menor fue la permeabilidad del envase. Existieron diferencias entre el uso de Extendapak 1® frente a Extendapak 47®, siendo Extendapak 1® la atmósfera más apropiada en todos los casos, ya que mantuvo las características iniciales durante más tiempo que el resto.

Palabras clave adicionales: aceptabilidad sensorial; análisis sensorial; atmósfera modificada; productos elaborados y refrigerados; sous vide; vida útil.

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Introduction

'Reineta', 'Reinette du Canada' and 'Reinette Grise du Canada' apple cultivars are traditional fruits of El Bierzo (León, northwest of Spain) (Guerra *et al.,* 2010). 'Reineta' is one of the two Spanish apples that is protected throughout the community as a Protected Designation of Origin (PDO), 'Manzana Reineta del Bierzo' (Commission Regulation (EC) Nº 2601/2001).

Roasted apple is a well-known dessert in Spanish homes. However, until now, industrial development has not been incorporated into the roasted apple process. In the past, studies related to processed apples have been focused on the dehydrated product (Nowak and Lewicki, 2001; Mandala *et al.,* 2005; Castello *et al.,* 2009), but there are no references to any of studies based on the comparison of different types of ovens, nor the adaptation of these ovens to the production of roasted apples, nor their influence on the characteristics of the final product.

Thermal treatments are intended to minimise the impact of processing on sensory and organoleptic characteristics of the product (Marcelo *et al.,* 2003a,b; Marcelo, 2004). There is relatively little information concerning the impact of heat treatments on sensory and organoleptic properties of apples. Kim *et al.* (1994) studied the effect of heat treatments on firmness of apples. The heat treatment (45°C, for 105 min) for apple cv. Golden Delicious and Delicious significantly increased their firmness, but no significant increase in firmness was observed for the apple cv. McIntosh. After storage period of 7 days at 2°C, the treated apples were firmer than those stored at 10°C, 18°C, and 25°C for the same length of time. Kim *et al.* (1993a) studied eleven apple cultivars. Changes in firmness, respiration rate, soluble solids and acidity measured in heat treated apples varied widely from one cultivar to another. The Golden Delicious cultivar showed a relatively strong tolerance to heat, so the Golden Delicious apples that received a heat treatment of 45°C produced slices with less browning and firmer texture compared to non-treated apples.

To reduce the deterioration which occurs when the apple is processed, different choices of treatments can be proposed depending on the apple cultivar. For more resistant cultivars, «minimal» physical treatments or novel technologies using various conditions of pressure, pH and temperature should be applied.

Roasted apple is *sous-vide* cooking system (Juneja and Snyder, 2007). After heating, these products are rapidly cooled and stored at refrigeration temperatures. Shelf life of *sous-vide* products at refrigeration temperatures is up to 42 days (Gorris and Peck, 1998). It is well known that heat treatments alter the structural, mechanical and surface properties of agrofood products (Sila *et al.*, 2005). Modified atmosphere packaging (MAP) combined with refrigeration has proved to be an effective preservation method to extend shelf life and quality retention of a large variety of fresh chilled food products such as red meat, poultry, fruits, vegetables, bakery products, fresh pasta and fish products (Mangaraj and Goswami, 2009). There has been a lot of works done to evaluate the influence of MAP on the shelf life of fresh apples and minimally processed apples (Rocha and Morais, 2000; Rocculi *et al.,* 2004). Studies have been also conducted to study the effect of MAP conditions on the sensory quality of roasted nuts (Ucherek 2001, 2004). However, no work has been done on roasted apples.

MAP cook-chill is commonly used to support and to lengthen the shelf life of many nutritious products. MAP generated within the packaging films chosen has been found to have the biggest influence on quality (Cliffe-Byrnes and O'Beirne, 2007). MAP uses plastic polymers with different permeabilities to the oxygen, CO_2 and water steam to lengthen the shelf life of fruits and vegetables (Jacobsson *et al.,* 2004). The evolution of the atmosphere inside the package containing the fresh products is the result of gases given off by the product and of the diffusion of the gases across the film (Kader *et al.*, 1989). Anaerobic systems have been shown to enable a extension of shelf life for a variety of cooked products (Church and Parson, 1995). Several procedures have been used to obtain roasted apple cv. Reineta combining the use of different kinds of electric and microwave ovens with pasteurization (Marcelo *et al.*, 2003a,b; Marcelo, 2004). The procedure that Marcelo *et al.* (2008) recommended for Reineta consists of: roasting, packing in a flexible bag and finishing the process with pasteurization. Marcelo (2004) indicated that the shelf life of roasted apple cv. Reineta without packaging was 9 days at 3°C, whereas the shelf life was prolonged to 42 days when the product was packaged, vacuum sealed in a plastic bag with a pressure of –0.1 MPa and pasteurised. Several studies have been

Abbreviations used: MAP (modified atmosphere packaging), PCA (principal component analysis), PDO (protected designation of origin), SS (soluble solids), TA (titratable acidity), ULO (ultra low oxygen).

conducted on the optimum storage atmosphere for various fresh and minimally processed products such as apple, pear etc. (Soliva-Fortuny *et al.,* 2004; Oms-Oliu *et al.,* 2007) but there are no published reports on the influence of film and modified atmosphere on sensory quality of roasted apple.

The objective of this work was to apply sensory descriptive analysis techniques to characterize the changes in roasted apples cv. Reineta packaged in two commercial films with two different modified atmosphere conditions with a refrigeration at 3°C for a storage length of up to 210 days.

Material and methods

The experiment involved two factors: type of packaging (two types of package material combined with two different modified atmospheres) and storage time (15 levels). Once all the apples were roasted, they were divided into two groups. Half of the apples were packaged using LORE 90 COOK film and the other half were packaged using CN 300 film. Each group was subdivided into another two groups, corresponding to the two different modified atmosphere conditions: Extendapak 1® (100% N_2) and Extendapak 47® (7.0% CO_2 2.5% O_2 90.5% N_2). Then, the roasted apples were pasteurized, cooled and stored for different periods of time: 14, 28, 42, 56, 70, 84, 98, 112, 126, 140, 154, 168, 182, 196, and 210 days.

Fruit material

Apple (*Malus domestica* Borkh) cv. 'Reinette du Canada' grown in «El Bierzo» region, province of Leon (Spain) and stored for 60 days in controlled atmosphere ULO (ultra low oxygen) (2% O_2, 1% CO_2, 95% RH, 2°C) was transported to the University of León to be processed.

Processing

Roasted apple preparation

Fruit of uniform size (75-80 mm diameter) were allowed to ripen at room temperature (20°C) for 12 days (Marcelo *et al.,* 2003a). Then, the apples were washed with water, disinfected with chlorine solution 2% (w/v) containing sodium hypochlorite (chlorine active 40 g L^{-1}) (Soliva-Fortuny and Martín, 2003), and rinsed by pulverization with water. Finally, they were dried individually using filter paper. Before roasting, the central cores of the fruit were carved out using a circular knife of 12 mm of diameter, to remove both the calyx and the seeds, but preserving the apple's peduncle. Lots of six apples each were randomly chosen and these apples were roasted at 200°C for 7 min using an electric oven (model 801 042 ES, Siemens, Co., Madrid, Spain) with upper heat as described in «Elaboration of the roasted apples» (Marcelo *et al.,* 2008).

Packaging material and atmosphere

When the internal fruit temperature dropped to 40°C, apples (180-200 g) were individually packed and sealed using a compensated vacuum machine (Workshops Ramón, S.L. Barcelona, Spain) and flexible plastic bags (Cryovac Grace Packaging Corp. Barcelona, Spain). Two commercially available polymeric films were used for the study as packaging material, LORE 90 COOK and CN 300 (Table 1). Two modified atmosphere packaging (MAP) types were also used, Extendapak 1® and Extendapak 47® (Table 1).

Pasteurization process

Once the roasted apples were packaged, the apples were pasteurized using a horizontal cylindrical autoclave (Ilpra Systems, corp. Barcelona, Spain). To avoid damage on the plastic pouches, pasteurization was done in the autoclave by spraying the apples with water instead of steaming them (Bourles *et al.,* 2009). A heat treatment was then applied for 13 min at 85°C (pasteurization value PV_{70} in core 411.09 min). The time and temperature that were recorded were converted to pasteurization values using a reference temperature of 70°C and a *z*-value of 10°C (González-Fandos *et al.,* 2004). These time and temperature combinations make the roasted apple valuable in terms of sensory quality. These parameters exceed the time and temperature parameters needed for microbiological stability. According to Marcelo (2004), since the pH of the 'Reinette du Canada' apple is very low, with values close to 3.3, there is no risk of *Clostridium botulinum*, nor risk of aerobic mesophile bacteria, nor moulds and yeasts nor enterobacteria in the samples that have been stored for

Table 1. Properties of the films and the modified atmosphere packaging (MAP) types used in the study

	Film 1	**Film 2**
Polymer	LORE 90 COOK (PA 20%, HDPE 70%) Polyamide- high density polyethylene	CN 300 several layers coextrusion [Polypropylene (PP) + Vinyl alcohol (EVOC) + Ethylene acetate vinyl and resin adhesive]
Manufacturer	Cryovac	Cryovac
Remarks	Cook in packaging material	Cook in packaging material, retractile
Thickness (μm)	90	60
Area (cm^2)	225	225
Void volume (cm^3)	420	420
O_2 transmission rate[a] ($mL\ m^{-2}\ day^{-1}\ atm^{-1}$)	400	15
CO_2 transmission rate[b] ($mL\ m^{-2}\ day^{-2}\ atm^{-1}$)	1,500	Nearly 0
Water vapour transmission rate[c] ($g\ m^{-2}\ day^{-1}$)	2.6	2
	MAP-A	**MAP-B**
Commercial denomination	Extendapak 1®[d]	Extendapak 47®[d]
Composition	100% N_2	7% CO_2, 2.5% O_2, 90.5% N_2
No. FDS	089 A1	300-15-13E

[a] Measured at 23°C and 0% RH (ASTMD-3985). [b] Measured at 23°C and 0% RH (ASTMD-3985). [c] Measured at 38°C and 90% RH (ASTMD-E-96/E). [d] ®Praxair, Inc.

35 weeks in refrigeration conditions. Finally the pasteurized product was cooled in a refrigerator (Ilpra Systems, corp. Barcelona, Spain), so that the temperature of the apple reached a temperature of 10°C in 30 min (Marcelo *et al.,* 2008).

Conservation of the roasted apples

The apples were stored in refrigerated exhibitors with a temperature of 3°C and with light exposure (960-1390 lx). The maximum storage period was 210 days.

A total of 178 apples were selected for each type of packaging and storage time. The samples were split into 3 subsamples, one for the difference test, one for the QDA test and one for the instrumental analyses.

Soluble solids, titratable acidity and pH

Every 14 days, titratable acidity (TA), soluble solids (SS) and pH were tested from the juice obtained from the roasted apples. There were 40 apples sampled for each type of packaging and storage time. TA was measured according to Schijvens *et al.* (1998) by titrating 25 mL of juice with 0.1 N NaOH up to pH 8.1 using a digital pH meter (model W.T.W. 526, Weilheim, Germany). Acidity was expressed as malic acid (%). SS content of juice (%) was determined at 20°C with a digital refractometer (model Atago PR1, Tokyo, Japan).

Sensory evaluation

Sensory analyses were carried out in a laboratory equipped with individual booths (AENOR, 1997). The samples were randomly offered to the panellists using an experimental design of balanced complete blocks.

Difference test

The difference test consisted of triangle tests which were performed every 14 days. Each panellist received

three coded apples (two of them identical and the other one different) randomly distributed in order to compare the stored packaged apple with a newly roasted apple. Forty-two panellists were asked to identify the apple which was different (AENOR, 1997; Schafheitle and Light 1989). The number for each apples per sample was 126 (42 panellists × 3 apples) for each type of packaging and storage time. The panellists were trained for 4 hours in two different sessions; they were recruited from the students (50% male, 50% female, 18-31 years of age) and staff (50% male, 50% female, 26-62 years of age) of the University of León (Ponferrada campus) and were only allowed to participate in the study if they regularly ate roasted apples. The roasted apples were warmed up in lots of 6 pieces for 2 min in a microwave oven and they were kept in a water bath with a core temperature of 50°C prior to testing. Three apples (each one weighing 180-200 g) were served to each panellist (Marcelo, 2004). The panellists had to find out wich apple was different by attending to its external aspect and flavour.

The end of sensory acceptability period for roasted apple was set to the storage time when significant differences between the newly elaborated apples and the stored apples (14 to 210 days) were found ($p \leq 0.05$).

Quantitative descriptive analysis

Twelve panellists selected from the panel that was used in the «difference test» participated in four training session according to AENOR (1997). The number of apples per sample was 12 (1 apple per panellist) for each type of packaging and storage time. Sensory attributes, selected from the Check List Method (Lawless and Heymann, 1998) and from guidance sessions in accordance with AENOR (1997), were developed by comparing the roasted apples that had large differences in sensory qualities (Table 2). Once the descriptors were selected, a consensus about their usage was reached; the descriptors were precisely defined to evaluate them in order to quantify attribute intensity. For the standardization of both the descriptors and the panel training, 288 roasted apples were used: newly roasted apples and roasted apples stored at 3°C for different periods of time were used in order to obtain samples with clearly different characteristics. The training involved two stages, the first stage (two 20 min sessions), used each descriptor, in which panellists ranked four apples that were aged for different lengths of time, until the panel was homogeneous in its assessments – Kendall's W coefficient ≥ 0.7 (Moskowitz, 1983). During the second stage (four 20 min sessions), the panellists used 100 mm unstructured scales to score roasted apples aged for different lengths of time, and the performance of the panel was calculated using a Principal Component Analysis (PCA), until there were no outliers in the group (King *et al.,* 2001). The panellists were also trained how to use a 100 mm continuous line scale anchored with «low» intensity at 10 mm and «high» intensity at 90 mm. A balanced complete block experimental design was carried out to evaluate the roasted apples. For each roasted apple, the perceived intensity of each attribute was indicated by placing a vertical line along the line scale (Jacobsson *et al.,* 2004; Cliffe-Byrnes and O'Beirne, 2007).

Statistical analysis

The data were analysed by using a two-way ANOVA procedure (SPSS Inc. Win version 15.0., SPSS Chicago,

Table 2. Sensory attributes assessed by the panellists

Attribute	Method of evaluation	Definition
External appearance	Appearance	Cracked and wrinkled skin
Internal appearance	Appearance	White and yellow colour similar to an apple newly roasted
Colour	Appearance	Colour similar to an apple newly roasted
Odour intensity	Aroma	Strength of the external odours in the apple sample. Characteristic aroma released during the chewing of the newly elaborated roasted apple
Sweet taste	Taste	One of the basic tastes (*e.g.* sucrose)
Acid taste	Taste	One of the basic tastes (*e.g.* malic acid)
Alcoholic taste	Taste	Off-taste associated with the deterioration or transformation of the sample
Juiciness	Taste	Amount of liquid released on mastication (after 4-5 bites), mouthfeel
Facility of cut	Texture	Force required to cut the sample with a knife
Hard zones	Texture	Presence of hard zones when cutting or lack of roast at the first bite

IL, USA) to test the differences between the effects of packaging (1-A: LORE 90 COOK + EXTENDAPAK 1®, 1-B: LORE 90 COOK + EXTENDAPAK 47®, 2-A: CN-300 + EXTENDAPAK 1®, 2-B: CN-300 + EXTENDAPAK 47®), storage time (14, 28, 42, 56, 70, 84, 98, 112, 126, 140, 154, 168, 182, 196 and 210 days) and to analyse the interaction between packaging and storage-time. Posthoc LSD tests were applied for multiple comparisons. A PCA without rotation was performed on the mean sensory scores to determine the relationship between the attributes and the samples.

Results

Soluble solids, titratable acidity and pH

The data concerning the effects of the different type of packaging on some of the physico-chemical characteristics of roasted apple during storage are shown in Table 3. No significant differences were observed between the four type of packaging for SS, TA and pH. Significant differences during storage time were found for TA, so the newly processed roasted apples (0 days) were significantly more acidic than stored samples. SS and pH did not substantially change during storage time. There were no significant differences in SS and TA for packaging × storage time interactions; however, these interactions were significantly different for pH.

Table 3. Effect of type of packaging and storage time on SS, TA and pH for the roasted apple cv. Reineta

	SS (%)	TA (% malic acid)	pH
Type of packaging[1]			
1-A	17.0[a2]	0.28[a]	3.66[a]
1-B	16.9[a]	0.28[a]	3.65[a]
2-A	16.9[a]	0.29[a]	3.66[a]
2-B	17.0[a]	0.28[a]	3.66[a]
Storage (days at 3°C)			
0	16.7[a]	0.52[a]	3.68[a]
14	17.0[a]	0.48[b]	3.67[a]
28	16.9[a]	0.42[c]	3.65[a,b]
42	17.0[a]	0.36[d]	3.62[b]
56	17.1[a]	0.32[e]	3.65[a,b]
70	16.9[a]	0.28[e,f]	3.66[a,b]
84	16.9[a]	0.27[f,g]	3.67[a,b]
98	16.9[a]	0.25[f,g h]	3.67[a,b]
112	17.0[a]	0.23[g,h,i]	3.62[b]
126	16.8[a]	0.22[h,i,j]	3.66[a,b]
140	16.9[a]	0.21[h,i,j]	3.64[a,b]
154	17.0[a]	0.21[h,i,j]	3.67[a]
168	16.9[a]	0.21[i,j]	3.65[a,b]
182	16.9[a]	0.19[j]	3.66[a,b]
196	17.0[a]	0.18[j]	3.68[a]
210	16.9[a]	0.18[j]	3.66[a,b]
Effect of packaging	ns[3]	ns	ns
Effect of storage time	ns	***	***
Effect pack × storage	ns	ns	***

[1] Type of packaging: 1-A: LORE 90 COOK + EXTENDAPAK 1®, 1-B: LORE 90 COOK + EXTENDAPAK 47®, 2-A: CN-300 + EXTENDAPAK 1®, 2-B: CN-300 + EXTENDAPAK 47®. [2] Means with the same letter are not significantly different (LSD, $p < 0.001$). [3] ns: non significant. *** $p \leq 0.001$.

Difference tests

No significant differences were found during storage time for sensory quality, according to the difference test, until the 84th day of storage (Table 4). This means that 70 days will be the limit for the sensory acceptability of the product, independent of the type of film and atmosphere in which the product was stored in. From the 84th day on, significant differences were found depending on which packaging material and which modified atmosphere were used to stored the apples. The type of packaging 1-B was the worst packaging material, because significant differences between the stored apples and the newly elaborated apples appeared earlier than in the other three types, whereas samples packaged in type of packaging 2-A did not to show significant differences with newly elaborated apples until the 126th day of storage. From the 168th day on, panellists were able to distinguish between the newly elaborated and the stored apples for all the type of packaging ($p \leq 0.001$).

Descriptive tests

Regarding to visual attributes, colour was the only attribute to show significant differences between type of packaging and between storage times (Table 5). The colour of 1-B was significantly lower than the type of packaging with MAP Extendapak 1®. During storage time, there was a gradual loss of colour, so after 154 days of storage, the colour of the roasted apples was

Table 4. Effect of storage time on the sensory characteristics for the roasted apple cv. Reineta according to the triangle test

Time (days at 3°C)	Type of packaging (film-MAP)			
	1-A	1-B	2-A	2-B
14	ns	ns	ns	ns
28	ns	ns	ns	ns
42	ns	ns	ns	ns
56	ns	ns	ns	ns
70	ns	ns	ns	ns
84	ns	*	ns	ns
98	*	*	ns	*
112	*	**	ns	**
126	**	***	*	**
140	***	***	*	**
154	***	***	**	***
168	***	***	**	***
182	***	***	***	***
196	***	***	***	***
210	***	***	***	***

Type of packaging : 1-A: LORE 90 COOK + EXTENDAPAK 1®, 1-B: LORE 90 COOK + EXTENDAPAK 47®, 2-A: CN-300 + EXTENDAPAK 1®, 2-B: CN-300 + EXTENDAPAK 47®. ns: non significant. * $p \leq 0.05$. ** $p \leq 0.01$. *** $p \leq 0.001$.

significantly lower than the colour of the newly elaborated apples. The interaction between packaging × storage time was not significant for any of the visual attributes.

In regards to olfactory-gustatory attributes, odour intensity, sweet taste and alcoholic taste were all influenced by the type of packaging (Table 5). Packaging type 1-B showed a significantly lower value of odour intensity than the type of packaging with MAP Extendapak 1®, also the Extendapak 1® samples were significantly sweeter than the Extendapak 47® samples, so it seems that MAP influenced the sweet taste descriptor. The Lore 90 Cook samples showed less alcoholic taste intensity than the CN 300 samples. No significant differences were found between types of packaging for acid taste. All the olfactory-gustatory attributes (odour intensity, sweet taste, acid taste and alcoholic taste) changed during storage. Alcoholic taste significantly increased after the 84th day, whereas the rest of attributes showed significant reductions during the storage period. Even though packaging × storage time interactions were not significant for odour intensity, sweet taste and acid taste, there were significant for alcoholic taste.

Juiciness was the only textural attribute to show different behaviour between type of packaging and between storage times (Table 5). Neither the facility of cut nor the presence of hard zones showed significant differences between type of packaging or across storage time. The juiciness of CN 300 samples was valued lower than the juiciness of the Lore 90 Cook samples. Moreover, juiciness significantly decreased during storage. Whereas the intensity of some of the descriptors such as odour intensity, acid taste and sweet taste, clearly decreased during the storage period, descriptors such as internal appearance, external appearance and facility of cut or hard zones hardly changed during the storage period. Alcoholic taste was the only descriptor that clearly increased during the storage period.

Principal component analysis

A PCA was conducted on the correlation matrix produced from the sensory data from the different type of packaging during storage time. The PCA plots gave a visual overview of how sensory quality was influenced by the different type of packaging and storage times. The principal components of 1, 2, 3 and 4 had eigenvalues that were greater than 1.0. The first three principal components (PCs) explained the 48.94% of the total variance (PC1: 27.72%; PC2: 11.00%; PC3: 10.23%) (Fig. 1I), and additional 10.06% was explained by PC4 (not shown). The loading plot for the first two PCs indicated that some of the attributes described the same variation among the samples. The underlying dimension for factor I were the olfactory gustatory attributes, with attributes such as acid taste (0.85), sweet taste (0.80) and odour intensity (0.70) loading positively; whereas alcoholic taste (–0.75) was negatively loaded and place on the left side of the plot. The second PC explained 11.00% of the variance and was loaded positively with presence of hard zones (0.65) and facility of cut (0.64). The third PC was loaded with internal appearance (0.65).

The PCA scores of the different type of packaging for the roasted apples (Fig. 1II) gives a visual representation of how the different type of packaging contribute to the maintenance of the initial characteristics of the roasted apple. Roasted apples stored in the protective atmosphere Extendapak 1® were positively loaded on axis 2, whereas roasted apples packed in the protective atmosphere Extendapak 47® were negatively loaded on axis 2. There was a considerable distance between CN 300 and Lore 90 Cook samples, since the CN 300 samples scored higher than Lore 90 Cook samples.

Table 5. Mean sensory scores of attributes for roasted apple cv. Reineta according to the type of packaging and the storage time (scale: n = 12, 0 = low, 10 = high)

	Visual attributes			Olfactory gustatory attributes				Textural attributes		
	External appearance	Internal appearance	Colour	Odour intensity	Sweet taste	Acid taste	Alcoholic taste	Juiciness	Facility of cut	Hard zones
Type of packaging[1]										
1-A	6.5^{a}	6.7^{a}	6.7^{a}	7.0^{a}	7.4^{a}	6.8^{a}	0.7^{b}	7.7^{a}	6.6^{a}	6.5^{a}
1-B	6.7^{a}	6.7^{a}	6.1^{b}	6.4^{b}	6.6^{b}	6.5^{a}	1.0^{b}	7.5^{a}	6.7^{a}	6.4^{a}
2-A	6.7^{a}	6.8^{a}	6.7^{a}	7.0^{a}	7.2^{a}	6.9^{a}	1.8^{a}	6.9^{b}	6.6^{a}	6.5^{a}
2-B	6.7^{a}	6.6^{a}	6.5^{a,b}	6.8^{a,b}	6.7^{b}	6.5^{a}	1.8^{a}	7.0^{b}	6.7^{a}	6.6^{a}
Storage (days at 3°C)										
14	6.9^{a}	6.6^{a}	7.2^{a}	8.3^{a}	7.8^{a}	7.9^{a}	0^{h}	8.0^{a}	6.7^{a}	6.0^{a}
28	7.0^{a}	6.8^{a}	7.1^{a}	8.2^{a,b}	7.8^{a}	7.8^{a}	0^{h}	7.9^{a}	6.6^{a}	6.4^{a}
42	6.9^{a}	6.8^{a}	7.0^{a,b}	8.0^{a,b,c}	7.7^{a,b}	7.7^{a,b}	0^{h}	7.7^{a,b}	6.7^{a}	6.8^{a}
56	6.6^{a}	6.7^{a}	7.0^{a,b}	7.8^{a,b,c,d}	7.5^{a,b}	7.5^{a,b,c}	0^{h}	7.8^{a,b}	6.5^{a}	6.4^{a}
70	6.7^{a}	6.7^{a}	6.9^{a,b,c,d}	7.5^{b,c,d,e}	7.3^{a,b,c}	7.2^{a,b,c,d}	0.2^{g,h}	7.5^{a,b,c}	6.5^{a}	6.2^{a}
84	6.7^{a}	6.8^{a}	6.8^{a,b,c,d,e}	7.3^{c,d,e,f}	7.2^{a,b,c,d}	7.0^{b,c,d,e}	0.7^{g}	7.5^{a,b,c}	6.6^{a}	6.6^{a}
98	6.9^{a}	6.5^{a}	6.6^{a,b,c,d,e}	7.1^{d,e,f,g}	7.1^{a,b,c,d,e}	6.9^{c,d,e,f}	0.9^{g}	7.5^{a,b,c}	6.5^{a}	6.8^{a}
112	6.6^{a}	6.7^{a}	6.5^{a,b,c,d,e}	6.8^{e,f,g,h}	6.9^{b,c,d,e,f}	6.6^{d,e,f,g}	1.1^{f,g}	7.4^{a,b,c}	6.9^{a}	6.7^{a}
126	6.8^{a}	6.5^{a}	6.3^{a,b,c,d,e}	6.6^{f,g,h,i}	6.8^{c,d,e,f}	6.4^{e,f,g,h}	1.5^{e,f}	7.2^{a,b,c}	6.7^{a}	6.4^{a}
140	6.8^{a}	6.9^{a}	6.4^{a,b,c,d,e}	6.3^{g,h,i,j}	6.6^{c,d,e,f}	6.2^{f,g,h}	1.8^{d,e}	7.1^{a,b,c}	6.3^{a}	6.3^{a}
154	6.5^{a}	6.6^{a}	6.1^{b,c,d,e}	6.1^{h,i,j,k}	6.5^{d,e,f}	6.1^{f,g,h}	2.1^{c,d}	6.8^{b,c}	6.9^{a}	6.6^{a}
168	6.6^{a}	6.7^{a}	6.0^{c,d,e}	6.0^{i,j,k}	6.4^{e,f}	5.9^{g,h}	2.3^{b,c}	6.6^{c}	6.5^{a}	6.6^{a}
182	6.5^{a}	6.7^{a}	5.9^{d,e}	5.7^{j,k}	6.3^{f}	5.8^{h}	2.6^{b}	6.7^{c}	6.9^{a}	6.4^{a}
196	6.3^{a}	6.6^{a}	5.8^{e}	5.6^{j,k}	6.3^{f}	5.7^{h}	3.1^{a}	6.6^{c}	6.6^{a}	6.6^{a}
210	6.4^{a}	6.6^{a}	5.9^{d,e}	5.5^{k}	6.3^{f}	5.7^{h}	3.6^{a}	6.5^{c}	6.4^{a}	6.4^{a}
Effect of packaging	ns	ns	***	***	***	ns	***	***	ns	ns
Effect of storage time	ns	ns	***	***	***	***	***	***	ns	ns
Effect packaging × storage	ns	ns	ns	ns	ns	ns	***	ns	ns	ns

[1] Type of packaging: 1-A: LORE 90 COOK + EXTENDAPAK 1®, 1-B: LORE 90 COOK + EXTENDAPAK 47®, 2-A: CN-300 + EXTENDAPAK 1®, 2-B: CN-300 + EXTENDAPAK 47®. ns: no significant. * $p \leq 0.05$. ** $p \leq 0.01$. *** $p \leq 0.001$.

Apples packed in the Extendapak 47® packaging were closer on the graph than apples packed in the Extendapak 1® packaging. This means the scores of the roasted apple samples stored that the packaging material had less influence on scores of the roasted apple samples stored in the Extendapak 47® packaging than in the Extendapak 1® packaging.

The samples were separated along the PCs according to the score of roasted apple in each of the four type of packaging affected by storage time (Fig. 1A, 1B, 2A, 2B). The apples which were recently roasted (day 14) were clustered near axis 1, positively loaded and to the right in the plot for all type of packaging, except for the type of packaging 1-B, which was located with very low negative values. During storage, the CN 300 type of packaging were very similar, so the scores were plotted from highly positive values to very negative values along axis 1 and with values close to axis 2. Another similarity occurred between the type of packaging, so the Lore 90 Cook samples were spread out over the plot, whereas the CN 300 samples tended to remain clustered around the axis.

Discussion

The fact that no changes were observed in SS during the period storage was probably due to the contribution of organic acids, pectin substances and other sugars to the SS content (Kim *et al.,* 1993b). Kim *et al.* (1993a) also reported no changes in SS of several apple cultivars during storage.

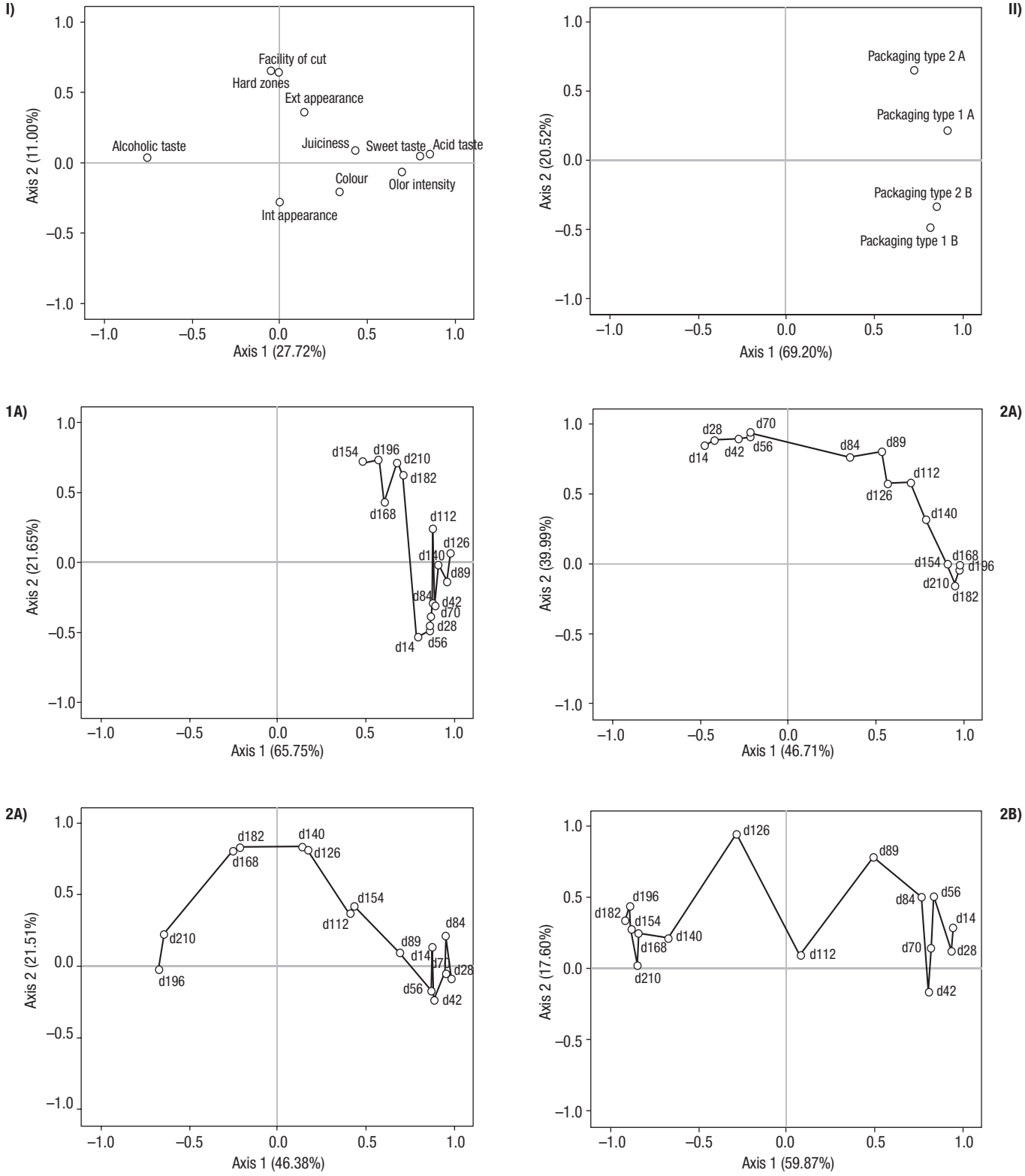

Figure 1. I: PCA loadings of the quality attributes of roasted apple derived from different types of packaging at different storage times. II: PCA scores of four different types of packaging for the roasted apple sample. PCA scores of roasted apple for four different types of packaging affected by storage time: 1A (Lore 90 Cook + Extendapak 1®), 1B (Lore 90 Cook + Extendapak 47®), 2A (CN-300 + Extendapak 1®), B (CN-300 + Extendapak 47®).

A decline in acidity was observed during the storage period following an exponential function ($R^2 = 0.9228$), whereas pH values were kept almost constant during the storage period, this is probably due to the effect of the buffering capacity of apple tissue (Rocha and Morais, 2003). In agreement with our results, González-Fandos *et al.* (2004) found that pH did not change significantly throughout the storage period in rainbow trout (*Oncorhynchus mykiss*) processed by the sous vide method. This pH stability may have several positive implications: low activity of polyphenoloxidases in this range of pH, 3.5-3.7, and a reduced microbiological development, which will contribute to the preservation of the roasted apple (Marcelo, 2004).

Whereas Marcelo (2004) obtained a shelf life of 42 days for roasted apple cv. Reineta packed and sealed under vacuum in a plastic bag at –0.1 MPa before pasteurization, in this work the limit length of acceptability of the product increased to 70 days. This increase of acceptability could be due to the solubility of N_2 and to its competition with O_2 at chemical-enzymatic level (Rocculi *et al.,* 2004). This sensory acceptability was higher than 45 d of shelf life found by González-Fandos *et al.* (2004, 2005) for rainbow trout (90°C/3.3 min) and salmon (90°C/15 min) and than the 18 d of shelf life found by Díaz *et al.* (2009) for sous vide salmon cooked at 80°C for 43 min. According to Yesudhason *et al.* (2009), based on sensory score and microbiological data, the shelf life of seer fish steaks increased 9 d when samples were packaged in MAP.

The fact that panellists took more time to find the differences, between the stored samples and the newly elaborated samples, in type of packaging 2-A than in type of packaging 1-B, shows how lower permeability and MAP together with no oxygen or CO_2 contribute to retain the original sensory quality longer. According to Saxena *et al.* (2008), variations in the permeability of packaging films and the use of selective permeable packaging films affects the produce quality, and could also be beneficial in extending the shelf life of the produce. Oxygen increases from 0.5 to 21.3 kPa have been found to accelerate of the deterioration of roasted coffee, so its shelf life is shortened (Cardelli and Labuza, 2001).

The fact that the type of packaging 1-B samples were less valued for colour than MAP with 100% N_2 could be due to the initial presence of O_2 and CO_2 inside the type 1-B packaging, this factor that can lead to a less appropriate atmosphere for storage inside the packaging. Saxena *et al.* (2008) stated that initial gas concentrations in MAP significantly affect head space O_2 and CO_2 concentration during cold storage. The internal gas composition formed in different MA packages during storage affected the jackfruit bulb colour, so higher O_2 and CO_2 concentrations in the atmosphere assisted in oxidative browning which leads to lower appearance and colour scores for the product. Similar results were obtained by Cliffe-Byrnes *et al.* (2003) with coleslaw under MAP.

Regarding odour intensity, samples packed in 1-B scored lower than samples packaging MAP with 100% N_2. On the other hand, the results of previous research show how the development of anaerobic atmospheres under low permeable films, resulted in an overall poor sensory quality because of the development of off-odours (Cliffe-Byrnes and O'Beirne, 2007).

The Extendapak 1® (100% N_2) samples had sweeter taste than the Extendapak 47® (7 % CO_2 2.5% O_2 90.5% N_2) samples. It seems that the gaseous mixture in the Extendapak 47®, containing CO_2 and O_2, created an atmosphere inside the packaging less appropriate for the development of sweet taste (Kader *et al.,* 1989). The sweet taste characteristic of fresh cod loins was maintained longer under MAP conditions than in polystyrene boxes (Wang *et al.,* 2008). It has also been proved that hypoxic packaging in fresh carrots generate a sickeningly sweet taste, being highly correlated with carrot ethanol content (Seljåsen *et al.,* 2003). That would also explain why the lower permeability of the film, the higher the alcoholic taste of the roasted apple. Lower permeability films containing broccoli developed a slight to moderate alcoholic off-odours and had higher ethanol, acetaldehyde, and ethyl acetate contents, compared with broccoli in higher permeable bags (Deell and Toivonen, 2000).

The juiciness showed significant differences between the films scoring worse when the sample was stored in the less permeable container (CN 300). In agreement with these results, Cliffe-Byrnes and O'Beirne (2007) found that carrots packaged in less permeable film scored worse for juiciness than carrots packaged in more permeable film.

All the sensory attributes that changed during the storage period had a loss of intensity over time except for alcoholic taste, which increased after the 84th day until the end of the storage period (Table 5). According to Chiralt (2002), the loss of colour during storage is due to the alteration of the product pigments or to the reaction of colourless compounds induced by the treat-

ment. Low values of sweet taste and sugar content can contribute to a decline in taste (Seljåsen *et al.,* 2001). There was a loss in sweetness during the storage period. However, the SS did not change during the storage period. Vermeir *et al.* (2009) found a lower correlation ($R^2 = 0.62$) between the SS and the total concentration of sugars, indicating that other components such as acids also contribute to the SS. Kovacevic *et al*. (2008) has confirmed that sweetness was positively correlated with the amount of soluble solids, but also with total soluble sugars and fructose. Perkins-Veazie (1995) reported that the sugar:acid ratio is possibly more important for the perception of sweetness for the sensory panel than soluble solids alone. Guerra *et al*. (2009) also observed that TSS:TA was very useful to correlate positively with the sweetness sensory property during storage. Saxena *et al.* (2008) observed decreases in the overall acceptability score of Jackfruit under MAP conditions during storage due to off-odor and off-flavor which may be the result of anaerobic fermentation. Loss of aroma and flavour during storage has been reported in carrots under MAP (Cliffe-Byrnes and O'Beirne, 2007). Toivonen and DeEll (2001) observed gradual increases of alcoholic off-odors and an accumulation of ethanol, acetaldehyde, and ethyl acetate in the tissues of broccoli during 28 days under MAP at 1°C. In agreement with our results, acceptability scores for odour and taste of cooked air packaged MAP chub mackerel decreased with storage time (Erkan *et al.,* 2007). The textural attributes such as the facility of cut and the presence of hard zones did not show significant differences during the storage period. It is well-known that cooking fruit causes an initial loss of firmness due to membrane disruption and is associated with the loss of turgor (Thiel and Donald, 2000; Lillford, 2001). However, in fruit nuts such as roasted pistachios, texture attribute hardness was affected by storage time (Raei *et al.,* 2010). As reported in fresh and minimally processed apple (Mehinagic *et al.,* 2004; Varela *et al.,* 2007), the intensity of sensory descriptor juiciness decreased during the storage period.

As final conclusions, this study shows that sensory acceptability of roasted apple cv. Reineta stored under MAP in refrigeration conditions was useful to extend its sensory acceptability to 70 days. Sensory attributes such as colour, odour intensity, sweet taste, alcoholic taste and juiciness had significant differences between the different types of packaging. The less permeability the film, the better the original properties of roasted apple cv. Reineta were kept. There were significant differences between the modified atmospheres, in this case Extendapak 1® (100% N_2) was more appropriate than Extendapak 47® (7% CO_2 2.5% O_2 90.5% N_2) to keep the original characteristics of roasted apple cv. Reineta for a longer time. During the storage period, odour intensity, acid taste and sweet taste decreased, whereas alcoholic taste increased and the internal appearance, the external appearance, the facility of cut and the hard zones did not changed.

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