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ORIGINAL PAPER

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The effects of edible coatings on postharvest quality of the "Bravo de Esmolfe" apple

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Abstract Apples (*Malus domestica* Borkh cv Bravo de Esmolfe) were coated with a polysaccharide-based or a protein-based coating. Alginate and gelatine coatings at different concentrations, plasticized with glycerol and carboxymethylcellulose (CMC) plus sucroesters coatings plasticized with mono/diglycerides were tested. The effects of those coatings on the storage stability were followed by measurements of peel and pulp firmness, external L* a* and b* colour values, solid soluble content and weight loss during storage at 20 °C for three months. The 2 wt% alginate and 5 wt% gelatine coatings significantly reduced weight loss, thus maintaining fruit firmness and thereby preserving fruit freshness. The effects of those coatings also include the improvement of appearance and imparted an attractive natural-looking sheen to the fruit.

Keywords "Bravo de Esmolfe" apple · Edible coatings · Texture · Colour Weight loss

Introduction

Malus domestica Borkh cv Bravo de Esmolfe is a typical Portuguese apple cultivar classified as PDO (Protected Designation and Origin), which means that it corresponds to a traditional product produced under strict conditions and labelled with a specific law protected designation. This cultivar presents quite good sensory properties, namely sweetness (9.7% of reducing sugars and 13.5% of total solid soluble content) and flavour, but softens quickly in the postharvest period. To these fruits are also generally recognised the fast deterioration of the flavour during storage, making it difficult to meet market quality standards. Therefore, improvement on storage conditions should be achieved.

Aiming to control physiological activity of fruits, over the past 40 years, considerable research has been done on the use of edible coatings, as it is a cheaper and easier method as compared to other preservation methodologies. Edible coatings can create a modified atmosphere similar to controlled atmosphere by modifying internal gas composition retarding ripening and reducing decay [1, 2, 3, 4]. The modification of internal gas composition is achieved through the regulation of moisture, oxygen, carbon dioxide, lipid, aroma and flavour compounds transfer in food systems [5, 6]. The use of coatings can entrap aroma volatile compounds, thereby increasing their concentrations [1, 4]. However, a certain degree of oxygen and carbon dioxide permeability is necessary to avoid anaerobic respiration, which would result in physiological disorders and a rapid loss of quality. These goals may be attained through the use of semi-permeable coatings [7].

The functional characteristics required for a coating depends on the product matrix and on the deterioration processes the product is subject to. Potential applications and properties of edible films and coatings have been reviewed elsewhere [7, 8]. Proteins, lipids and polysaccharides are the main constituents of edible films and coatings. Among studied proteins are wheat gluten, corn zein, soy protein, rice protein, egg albumin, milk proteins and gelatine [9]. Regarding lipids, those include waxes, acylglycerols and fatty acids. Suitable polysaccharides include cellulose and derivatives, alginates, pectins, starch and derivatives and others [8]. Sucrose polyesters at different concentrations were effective for extending the shelf life of apples [10, 11].

Multivariate methods, in particular principal component analysis (PCA) and cluster analysis (CA), are important tools for identifying physical and chemical attributes of foods. CA group attributes into subsets, each one being more homogeneous that the attributes as a whole. The distance between objects in a multidimensional space is the Euclidian distance. If one had a two- or

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Table 1 Edible coatings composition

	Alginate[a]	Gelatin[a]	CMC[a]	Glycerol[b]	MDG[b]	SE[b]
1A	1.0	–	–	20	–	–
1B	1.0	–	–	50	–	–
1C	2.0	–	–	20	–	–
1D	2.0	–	–	50	–	–
2A	–	2.0	–	50	–	–
2B	–	2.0	–	20	–	–
2C	–	5.0	–	50	–	–
2D	–	5.0	–	20	–	–
3A	–	–	1.3	–	7.7	5.8
3B	–	–	0.8	–	25	187
REF	–	–	–	–	–	–

CMC—Carboxymethylcellulose
MDG—Mono/diglycerides
SE—Sucroesters
REF—Reference
[a] g/100 g solution
[b] g/100 g polymer

three-dimensional space this measure is the actual geometric distance between objects in the space. PCA is the statistic technique used to identify the smallest number of latent variables, called "principal components", that explain the greatest amount of observed variability. The score vectors, which relate the individual experimental samples to each other, could be used as response variables to identify significant factors and the loading vectors could be used to identify both the response variables describing the main variation and the response variables describing the same phenomena among the samples [12].

Having in mind the main constraints to the "Bravo de Esmolfe" apples preservation the aim of the present study was to determine the effectiveness of composite edible coatings in increasing the shelf-life of this apple's cultivar.

Material and methods

Fruit attributes. "Bravo de Esmolfe" apples were hand harvested in September in a NE of Portugal orchard and transported to the laboratory on the same day. The fruit were selected for their uniformity in size (diameter 65 to 70 mm), and freedom from defects while immature fruits were discarded. Raw material was analysed for external colour, firmness, pH, reducing sugars, total soluble solids content (SSC) and a_w.

The average values found for the physical-chemical raw material quality attributes were: firmness 9.4±0.10 (N); L* 78.3±0.50; a* 10.9±0.10; b* 36.60±0.07; pH 4.48±0.06 and SSC (%) 13.8±0.17; reducing sugars 4.5(%); a_w 0.9 (explained by a high solid soluble and sugar contents).

Coating materials. The coatings materials were provided by: Alginate (SATIALGINE S550)-SANOFI Bio, Industries; Carboxymethylcellulose (CMC) (-Blanose 7 MF)-Hercules; Gelatine; Mono/Diglycerides (MDG) Myvacet 5-07, 5DO1212-Quest International; Glycerol (p.a. grade Merck) and Sucroesters (SE) E 473-LWA 1570 (Mitsubishi Co.).

The coatings were prepared in aqueous solutions according to Table 1. All solutions consisted of the indicated wt% of the polymer and the amount of the plasticizer was based on the amount of the polymer. Components were mixed by magnetic stirring and warmed at 45 °C. The coating-forming solutions were then applied by dipping the apples for 15 s. After dipping in coating solutions, the fruits were drained at room conditions. By microscopy analysis it was ensured that all the tested coatings uniformly recovered the apples surfaces.

Fruit storage. Coated and uncoated fruits were kept at room temperature (20 °C) for three months.

Analytical control. Samples as identified in Table 1 and reference (uncoated) fruits were analysed for: peel firmness (FMAX) and pulp firmness (FM), colour, soluble solids content (SSC) and weight loss (WL). These parameters were quantified in fruits kept for 13, 49 and 97 days. Determinations were performed on four fruits per treatment.

Firmness was evaluated by a puncture test on the sides of the cubes prepared from quarters using a TA-XT2 texture analyser from *Stable Micro Systems* with a 50 kg load cell, equipped with a rounded 2 mm diameter flat-head steel probe. Peel firmness measurements were taken as the first peak force value obtained during the test to penetrate the fruit 7 mm at 1.5 mm/s and pulp firmness as the medium force.

Fruit colour was measured by the CIE L*a*b* system using a chroma meter (Minolta Colour Meter CR 200). A white tile (L*: 97.46; a*: –0.02; b*: 1.72) was used as reference.

SSC were determined by refractometer (Atago) in a combined sample of juice extracted from the four fruits.

Statistical analysis. Data were submitted to Principal Component Analysis (PCA) in order to establish the relationship between the quality attributes and tested samples, and to a discriminant analysis to confirm groups. "Statistica v. 5.0" software was used for the analysis.

Results and discussion

Mean values for the attributes of the coated and uncoated fruits were subjected to a Principal Component Analysis (PCA). By this analysis the space of seven variables (quality parameters significantly related to the two first factors) was reduced to a plane defined by two principal components (Factor 1 and Factor 2) accounting for 60.0% at the 13th day, 75.5% at the 47th day and 83.8% at the 97th day respectively of the total variance of the original data. Nevertheless, at the 13th day the third factor is needed to explain higher value of the total variation (77.15%). So, it may be stated that at the 13th day,

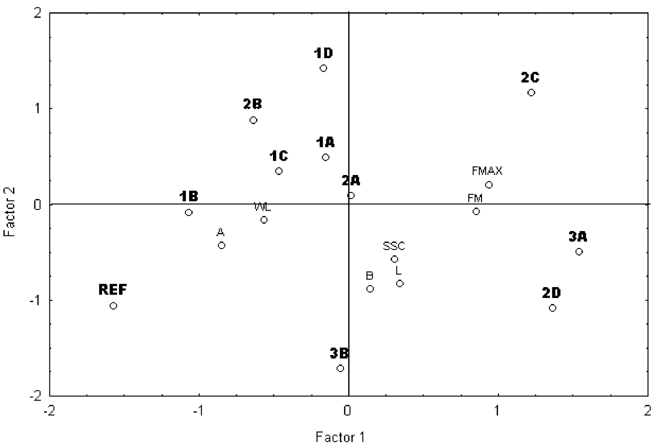

Fig. 1 Projection of quality attributes, uncoated and coated fruits in the plane of the two principal components (13th day)

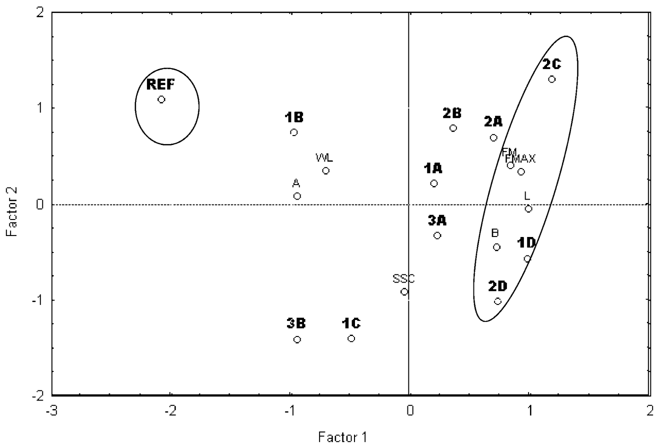

Fig. 3 Projection of quality attributes, uncoated and coated fruits in the plane of the two principal components (97th day)

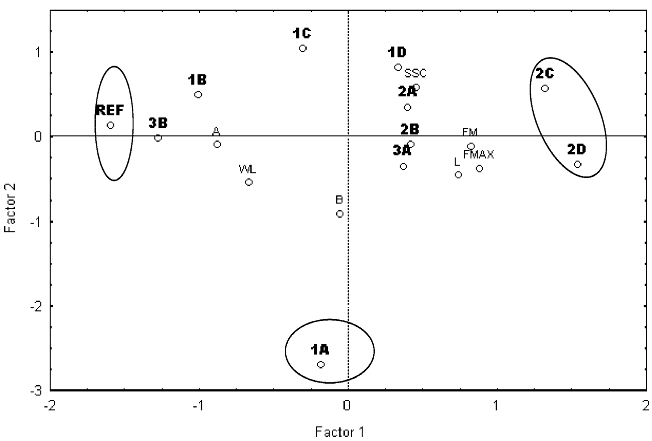

Fig. 2 Projection of quality attributes, uncoated and coated fruits in the plane of the two principal components (49th day)

differences among samples are not yet clearly established. The factor loadings showed that the majority of tested variables were related to the first factor. The peel and pulp hardness and a* colour values are always positive and significantly related to the first factor. The L* and b* colour parameters did not show a uniform pattern being related to both factors 1 and 2 depending on holding period.

Weight loss and SSC are negatively and significantly related to respectively first factor and second factor but only at the end of the 97 days.

Figures 1, 2 and 3 show the projections of quality attributes and cases (coated and uncoated fruits) in the plane of the two principal factors at different holding periods. Subsets were established according to a discriminant analysis.

Figure 1 reports to the results of the 13th day. At this holding period samples are not yet clearly separated, as the Euclidean linkage distances among samples are quite similar.

Table 2 Quality attributes for original material (OM) at zero day vs uncoated (REF) and coated fruits at 97th day

	L*	b*	FMAX	WL
OM	78.3±0.50	36.6±0.07	2.8±0.10	
REF	63.6±0.50	45.9±0.10	0.9±0.07	18.2
1A	69.9±0.49	50.3±0.12	1.4±0.10	17.2
1B	66.9±0.47	45.1±0.08	1.3±0.09	17.4
1C	69.0±0.50	48.3±0.07	1.1±0.08	15.2
1D	72.7±0.30	49.8±0.06	1.7±0.10	15.5
2A	72.2±0.48	49.1±0.10	1.7±0.08	15.8
2B	71.4±0.47	48.5±0.08	1.6±0.09	16.2
2C	73.3±0.30	48.3±0.06	1.9±0.10	13.2
2D	71.7±0.40	51.4±0.07	1.7±0.08	15.4
3A	69.8±0.35	50.4±0.08	1.6±0.11	18.0
3B	68.1±0.50	48.0±0.09	1.0±0.10	18.1

At the 49th day (Fig. 2) samples coated with alginate (1A—Euclidean linkage distance 52.1) and gelatine (2C and 2D—Euclidean linkage distance about 9) are those that are located at higher distances in relation to the reference. Those samples presented the best texture values being the harder ones. Regarding colour values, the same samples maintain the green colour.

At the end of the holding period, 97 days (Fig. 3), the separation among the samples is enhanced. As shown in Table 2, edible coatings produced on the bases of CMC were not suited to extending the shelf-live of "Bravo de Esmolfe" apple as they induced higher fruit weight loss (18%). The fruits coated with these polymer solutions presented results similar to the reference. Gelatine (5 wt%) (2C and 2D) and alginate (2 wt%) (1D) edible coatings were those that better preserved quality attributes, namely peel and pulp firmness, L* and b* colour parameters and reduced weight loss. This confirmed what has been reported in the literature, that CMC coatings are more permeable to water vapour and O_2/CO_2 compared to gelatine and alginate. Therefore the last ones are more effective in controlling respiratory activity. The preserving properties of gelatine coatings showed to be independent of the glycerol concentration. In the case of the alginate coatings the higher level of glycerol is needed in order to be a suitable film.

Beneficial effects of fruit coatings based on gelatine and alginate also include improvement of appearance and imparted an attractive natural-looking sheen to the fruit. These beneficial effects are also observed in the pulp of the fruit.

In conclusion gelatine and alginate edible coatings seems to be an efficient way in extending shelf-life of "Bravo de Esmolfe" apples even at room temperature. Further studies are needed in order to study the influence of coatings in what respects apple's flavour.

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