Polyphenol oxidase activity and colour changes of peeled potato (cv. Monalisa) in vacuum

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Abstract: Minimal processing of vegetables has some undesirable physiological consequences. The shelf life of peeled raw potatoes is limited by the onset of enzymatic browning at the cut surfaces. It is generally accepted that polyphenol oxidase (PPO) is the enzyme mainly responsible for this type of browning. This work aimed to study the effect of vacuum storage at 4°C on the colour, which is the main parameter limiting the shelf life of potato (cv. Monalisa). PPO activity was evaluated as well with the aim to investigate the relation with colour changes.

Keywords: potato; minimally processed; peeled; colour; polyphenol oxidase; PPO; vacuum; refrigerated storage; postharvest technology.

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1 Introduction

Potato gained recognition as an inexpensive and nutritive food in the 18th century and now is among the ten major food crops in the world. As food, the tuber crops are the cheapest sources of carbohydrates and provide considerable amounts of protein, thiamin, ascorbic acid and minerals (Salunkhe and Desai, 1984).

It is well established that the consumption of vegetables is good for health (Krause and Mahan, 1985). But as consumers become more health conscious in their food choices, they also have less time to prepare healthy meals. As a result, minimally processed products have become an important sector of the food industry due to their 'fresh-like' qualities, convenience and speed with which meals can be prepared.

An increasing number of people are consuming daily at least one meal out of the home (Gracia and Albisu, 2001). Food service operations often have to prepare large quantities of food, such as potatoes, vegetables, onions and carrots, in a short period of time. Often, they have to prepare (peel and cut) these products the day before consumption, which can lead to excessive losses of soluble and sensitive nutrients (Laurila et al., 1998). During the preparation stages, produce is submitted to operations where cells are broken causing enzymes to be released from tissues and put in contact with substrates. Enzymatic browning is the discolouration that results from the action of a group of enzymes called polyphenol oxidases (PPO) (Nicolas et al., 1994), and is one of the limiting factors of the shelf life of fresh-cut products.

Traditionally, conventional food processing achieves the prevention of browning through the heat inactivation of PPO, as with blanching and cooking. Nevertheless, the use of heat has also the potential to cause destruction of some food quality characteristics, such as flavour, texture and nutritional value (Zawistowski, 1991). Physical methods to prevent browning include reduction of temperature and/or oxygen, treatment with gamma-irradiation, high pressure, the use of modified atmosphere, or vacuum packaging. Vacuum packaging, which removes the air from the package, is now widely used to extend food shelf life and the quality of minimally processed products (Brody, 1989; Gorris and Peppelenbos, 1992; Martens, 1995; Varoquaux and Nguyen, 1994). The use of vacuum packaging greatly inhibits the progress of oxidative reactions and inhibits the growth of aerobic microorganisms, which generally lead to deterioration of foodstuffs during storage (Gorris and Peppelenbos, 1992).

The aim of this research was to investigate the relation between PPO activity and colour changes of peeled potatoes (cv. Monalisa) during refrigerated storage (4°C), in air and vacuum conditions.

2 Material and methods

2.1 Plant material

Potatoes (cv. Monalisa) were grown and harvested by Jorge Caseiro, Comércio de Produtos Alimentares Lda, in Marinhais, Portugal. They were stored at room temperature (~15°C) and covered with black plastic in the laboratory to avoid sprouting, until used in the experiments (within one week).

2.2 Processing and storage conditions

Potatoes were washed, first with tap water and then with chlorinated water (0.75% active chlorine), then peeled, and finally vacuum packed with a Multivac machine (Gastrovac, Wolfertschwenden, Germany). Packaging conditions were 1 mBar and 10 s, and 1.5 s for closing the bags (high vacuum is not advisable when dealing with leaving tissues like fresh cut potatoes are). Vacuum bags (23 cm × 23 cm) consisted of double layer polyethylene (PE) and an inner layer of polyvinylidene chloride (PVdC) with 65 μm thickness, permeability to O_2: 0.70 mL/(m^2.bar.24h) at 23°C and 50% RH, permeability to CO_2: 0.34 mL/(m^2.bar.24h) at 23°C and 50% RH and permeability to H_2O: 1.08 g/(m^2.24h) at 25°C and 100% RH. The PVdC is responsible for the barrier to humidity and gases and PE is coextruded for its water and vapour low permeability and mechanical resistance (Varoquaux and Nguyen, 1994; Martens, 1995).

The bags used for the control were perforated with one hole/cm^2 with 3 cm diameter, in order to allow air circulation. Both air and vacuum packed potatoes were stored in the dark at 4°C and 55% relative humidity (RH), during seven days.

Three replicates per day were prepared. Each day of storage each of three bags (0.700 kg of peeled potatoes) was removed from refrigeration, opened and potatoes were examined for weight loss, colour, PPO activity, titratable acidity and pH.

2.3 Weight loss

Bags were weighed (Sartorius basic, Sartorius, Goettingen, Germany) before and after storage, and the respective weights were registered. The results are presented as % of loss of the initial weight.

2.4 The surface colour

The surface colour of potato was measured using a hand-help tristimulus reflectance colorimeter (model CR-200 b, Minolta Corp, Ramsey, USA). Colour was expressed as the CIE-L* a* b* uniform colour space. L* indicates lightness, a* chromaticity on a green (–) to red (+) axis, b* the chromaticity on a blue (–) to yellow (+) axis (Francis, 1980).

2.5 Polyphenoloxidase activity

Polyphenoloxidase activity was performed according to the method described by Rocha et al. (1998). Activity was expressed as U/g/min.

2.6 Analysis of pH

The potato juice pH was measured with a potentiometer, Crison, model Micron pH 2001 (Crison Instruments, S.A., Barcelona, Spain).

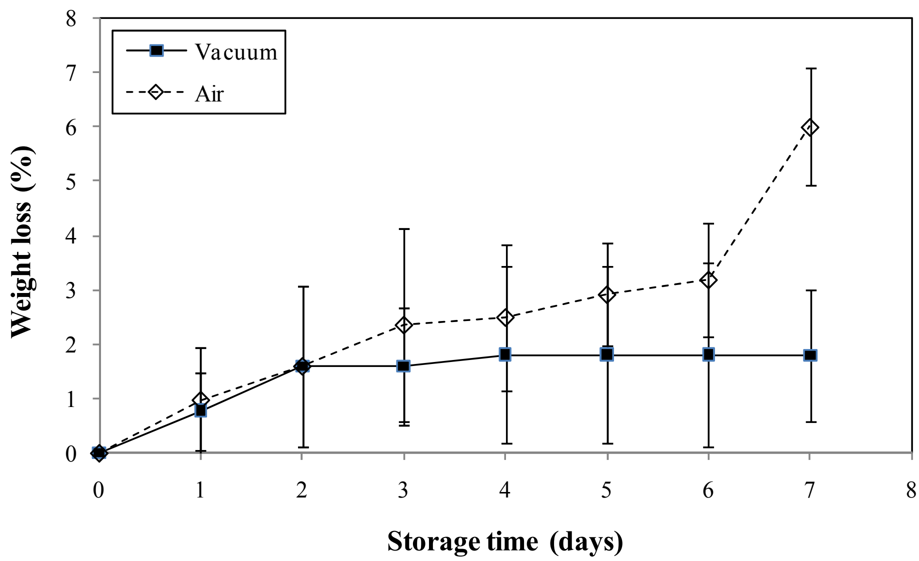
2.7 Titratable acidity

An aliquot of 25 g of potato was crushed and mixed with 250 ml of boiled distilled water. 25 ml of this solution was titrated with 0.1 N of NaOH, until reaching a pH of 8.3. This measurement was performed with a potentiometer with a combined electrode of pH Ingold U402-57/120 and a Crison MicropH 2002 (Crison Instruments, S.A., Barcelona, Spain). The results were calculated in g malic acid / 100 g potato.

2.8 Statistical analysis

The descriptive analysis consisted of the calculation of media and standard deviation for cardinal variables and of frequencies for ordinal variables. It was used the Kolmogorov-Smirnov test to verify the normality of the distribution of cardinal variables. Due to reduced sample size it was used the *Mann Whitney* test (non-parametric) to compare medium orders of non independent samples. The *Mann Whitney* test was used to compare media orders of two independent samples and the Kruskal-Wallis to compare media orders of three or more independent samples. The *Spearman* correlation coefficient was calculated to quantify the intensity between pairs of variables (non-parametric correlations) (Finney, 1980). P level of critical significance was used to reject null hypothesis (rejected when $p < 0.05$).

Figure 1 Weight loss (%) of vacuum and air packed peeled potatoes (cv. Monalisa) during storage at 4°C (see online version for colours)



3 Results and discussion

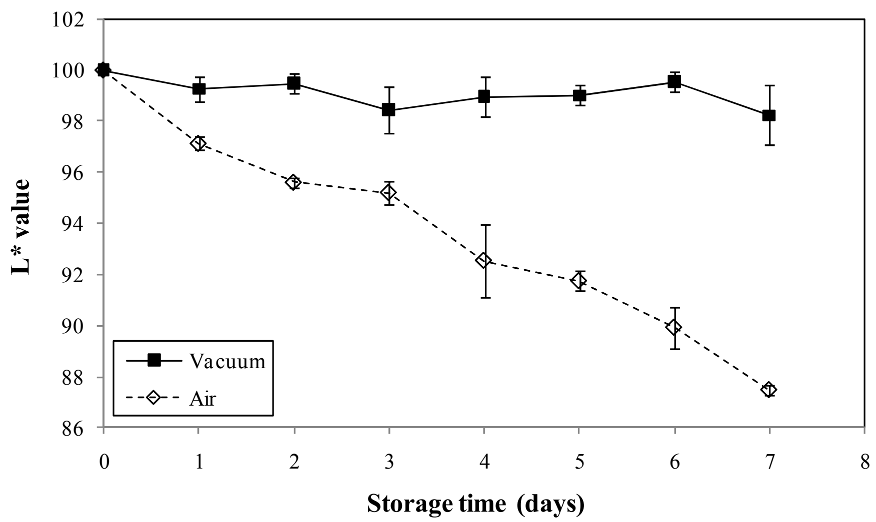
3.1 Weight loss

The weight loss of air packed potatoes increased during storage (Figure 1). After six days of storage, it reached 6% probably due to the low RH (55%) in the storage room. Differences between weight loss of air and vacuum packed potatoes were significant after the 7th day of storage ($p < 0.05$). This is probably due to the vacuum package, since moist food did not dry out because there is no air to absorb the moisture from the food (Rocha et al., 2003). Therefore, the water transfer from the heart to the moist surface was reduced in relation to air exposure. In addition, vacuum packaging reduces respiration rate and, thus, less substrate is used, which reduce the losses of fresh matter. This beneficial effect of vacuum storage may have important implications on a commercial point of view, since products are sold on a weight basis.

3.2 Changes of colour and PPO activity as related to browning

Only L* and a* values seemed to be related to the extent of browning, as already described by other authors (Sapers and Douglas, 1987). As found by Cantos et al. (2002), the best indicator of browning in fresh cut potato was the L* parameter (lightness factor). A decrease in L* value and an increase in a* value are indicators of browning, as stated by several other authors (Mastrocola and Lerici, 1991; Monsalve-Gonzalez et al., 1993; Sapers, 1989). There were no relevant changes in b* parameter (data not shown).

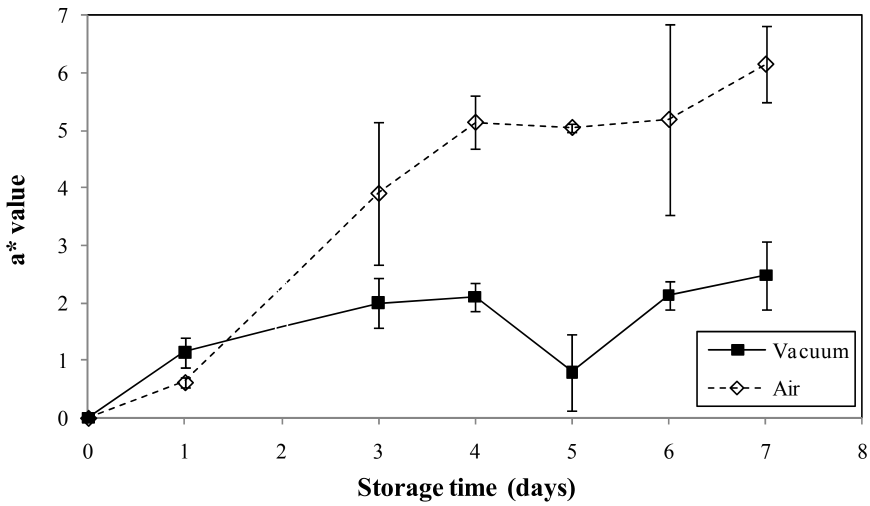
Figure 2 L* value of vacuum and air packed peeled potatoes (cv. Monalisa) during storage at 4°C



The L* value of vacuum packed potatoes was almost constant during storage revealing the beneficial influence of vacuum conditions when compared to air stored samples, whose L* value decreased significantly by 12% ($p < 0.05$) (Figure 2). Similar results were found in another study with 'Désirée' variety (Rocha et al., 2003). Additionally, the increase of a* value observed on air packed potatoes was significantly reduced in vacuum packed potatoes, which increased only slightly during storage ($p < 0.05$) (Figure 3).

These results are considered quite satisfactory as the peeled potatoes were stored in vacuum for seven days, in comparison with the shelf life of 14 days reported by Chassery and Gormley (1994) and considering that in our study no chemical additives were used in order to meet consumer's concern about fewer chemicals in foods.

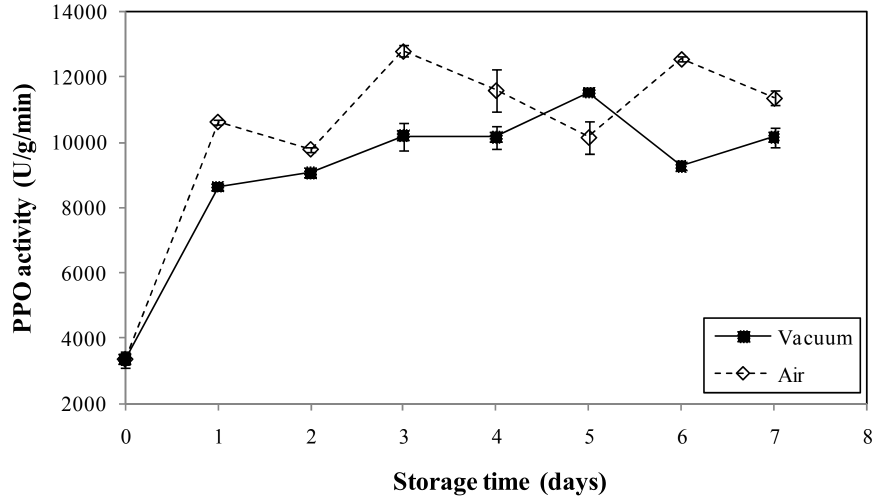
Figure 3 a* value of vacuum and air packed peeled potatoes (cv. Monalisa) during storage at 4°C



PPO activity of vacuum and air packed potatoes presented a dramatic and significant increase ($p < 0.05$) after minimal processing operations (day zero), as already found in a study with minimally processed apples (Rocha and Morais, 2001). After the third day, PPO activity revealed a tendency to stabilise although there were some fluctuations especially for air packed potatoes (Figure 4). PPO activity of vacuum packed potatoes was lower than for air stored samples, except on day 5. Apparently, the vacuum storage effectively inhibited the activity of the enzyme avoiding the darkening of potatoes, as already found in a similar study with 'Désirée' potatoes (Rocha et al., 2003). However, differences were only significant ($p < 0.05$) on days 3, 6 and 7. Heimdal et al. (1995) also found that enzymatic browning of lettuce was inhibited by moderate vacuum packaging in 80 μm PE bags, during about three weeks. The observed increase of PPO activity of all samples until the 3rd day of storage might suggest a *de novo* synthesis of PPO induced by the cutting of the vegetal tissue during the preparation of the samples (Cantos et al., 2002) or by cooling (Stewart et al., 2001) during the subsequent storage at low temperature (4°C). Rocha et al. (2007b) reported a similar behaviour in peeled carrot.

No significant correlation was found between colour changes and PPO activity (data not shown). Although differences in PPO activity between air stored samples and vacuum packed samples were not so high, the difference in colour was, perhaps due to the oxidation of phenols, which in exposure to air is higher than in its absence.

Figure 4 PPO activity of vacuum and air packed peeled potatoes (cv. Monalisa) during storage at 4°C



3.3 *pH and titratable acidity*

A decrease was observed on titratable acidity of potatoes (Figure 5); nevertheless, those changes did not seem to affect the pH value (Figure 6). This is desirable from the sensory point of view, since a variation in pH value would most certainly imply a negative change in flavour (Huxsoll and Bolin, 1989). During storage, there was a slight acidification (decrease of pH) of the vacuum packed samples, which process had also been observed in other potato cultivar, 'Désirée' (Rocha et al., 2003).

Differences between pH value of air and vacuum air packed potatoes were significant only after six days of storage ($p < 0.05$) (Figure 6).

Figure 5 Titratable acidity of vacuum and air packed peeled potatoes (cv. Monalisa) during storage at 4°C

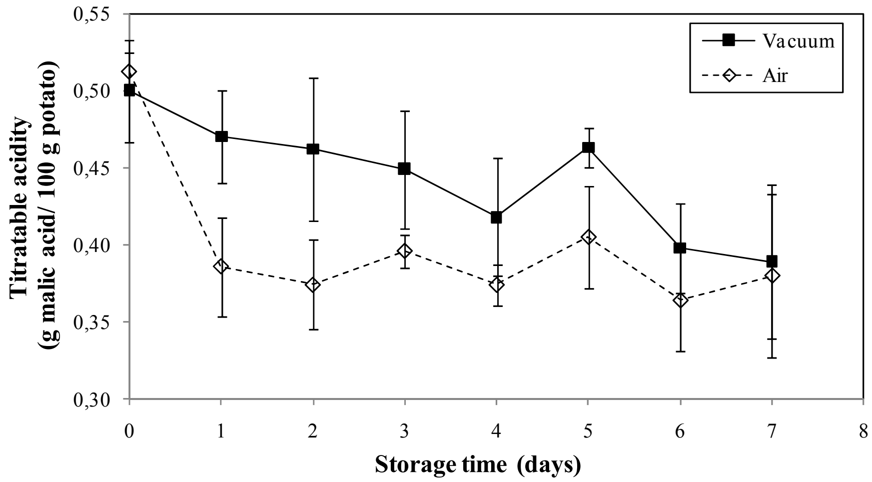
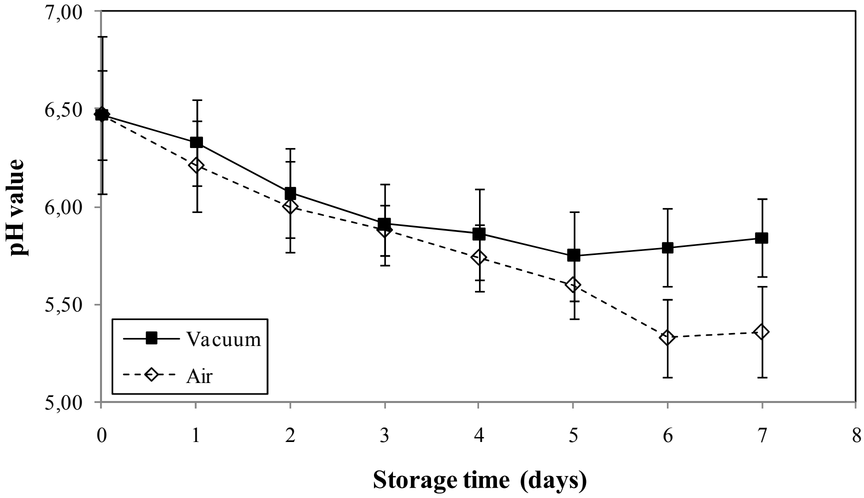


Figure 6 pH value of vacuum and air packed peeled potatoes (cv. Monalisa) during storage at 4°C



4 Conclusions

In this study, vacuum packaging of minimally processed potatoes was found to be an effective method to maintain colour parameters and to reduce PPO activity of potato (cv. Monalisa) for one week at 4°C.

Considering that enzymatic browning is one of the most limiting factors on the shelf life of fresh-cut products, the shelf life of minimally processed potatoes (cv. Monalisa) can be extended during one week at 4°C under vacuum.

The knowledge of the impact of minimal processing operations on fresh products will be an advantage for producers to reach new markets and for the consumer/food service actors, since they will have a new range of highly convenient products. Catering and foodservice operators deal every day with the problem of preparing great quantities of vegetables to integrate into soup and/or the main dish. These operations are labour and time consuming, so these institutions can save money and time by using pre-prepared products, such as this peeled potato under vacuum.

However, since the reduction of oxygen in the package may lead to the development of anaerobic microorganisms, it is necessary to ensure the microbiological safety of this type of products. Nevertheless, a similar type of product, vacuum packed peeled carrot, is already being commercialised in Portugal and microbiological evaluation previously performed by an independent laboratory allowed a shelf life of ten days (Rocha et al., 2007b). The microbiological analysis of grated carrot (Rocha et al., 2007a) together with sensory analysis showed that the shelf life of this product under vacuum was extended to eight days.

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