Evolution of Colour in Dried Fruit Storage: Relation between Colour and SO2 Content

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Abstract:- The objective of this work was to analyse the changes in colour and SO_2 content of dried apricots and raisins packaged in glass jars and polypropylene trays thermo sealed with different films with two layers of polymers: oriented polyamide OPA + polyethylene PE, polyamide PA + polypropylene PP and polyamide PA + polyethylene PE. Samples were stored at constant temperature ranging from cool to warm (5, 15, 25 and 35/40ºC). Before sealing, some jars and trays were purged with nitrogen, but most of them were sealed with air. The samples were analysed over a period of 12 months. In addition, the relation between fruit colour and SO_2 content changes has been assessed. This study shows that the temperature is the main factor affecting colour changes of dried fruit during storage. In addition, as the temperature increases, the SO_2 content decreases, and the samples become darker due to the Maillard browning reactions.

Keywords:- *Colour; Sulfur Dioxide; Dried Apricots; Raisins; Packaging; Storage.*

I. INTRODUCTION

For 6000 years, drying has been a successful method for preserving vegetables, fruit, cereals, meat and fish. Water content reduction below certain level inhibits microbial growth of yeasts and most bacteria on fruits and vegetables, enzymatic reactions and other processes which affect quality and appearance. Controlling the initial moisture content and its migration is critical to the quality and safety of foods (Weinberg et al., 2008).

However, the drying process itself may reduce quality and limit the market value and the demand for dried foods. The assessment of parameters such as shape, colour, texture, flavour and nutritional characteristics is crucial in the investigation of dried food quality. Besides, sensory properties of products dried can be damaged, due to the heat sensitivity of pigments, vitamins and nutrients of most fruits and vegetables, causing significant loss of the original colour and content of these substances (Link, Tribuzi, & Laurindo, 2017).

Colour is not only the most important sensory property that provides information about the quality of human perception but it is also an important classification factor for most food products (Wu & Sun, 2013), because consumers first rate the food by colour, then by taste and aroma. The colour of foods undergoes various changes during storage that can sometimes be detrimental to the quality and acceptability of the food; the higher the temperature and relative humidity under which it is stored, the greater the changes. In the case of dehydrated foods, good retention of the characteristic colour of the fresh product must be allowed (Yadav & Singh, 2014).

To decrease the effect of spoilage reactions, to facilitate the drying process and to improve the product quality, pre-treatment with sulfite before drying is commonly used. Sulfur dioxide has strong anti-bacterial properties that help prevent bacteria and yeast from growing in the product and preserve colour and nutrients.

Fresh fruits are seasonally available and drying enables them to be sold all year round (Chang, Alasalvar & Shahidi, 2016). Overall 2017/2018, dried fruit production reached the amount of 2.8 million tonnes, up by 16% compared with the previous 10-year average. In that season, dried grapes accounted for 42% of the world dried fruit share, followed by table dates with 36%. Prunes, dried apricots and dried figs accounted for the remaining 22%. Dried grapes production was 1.2 million tonnes and dried apricots 0.27 million tonnes (Driedfruit.net, 2021).

The quality can be maintained during storage by means of a proper choice of the packaging material, atmosphere, temperature and other storage conditions. During this period, moisture forms from Maillard reactions and is exchanged with the surrounding environment through the packaging, which mainly adversely affects texture, taste and colour.

To measure colour of fresh or dried fruits and vegetables, total colour variation of different sample of the same fruits and vegetables and total colour change of processed edible items, CIE L*a*b* coordinates are preferable (Waskale & Bhong, 2017).

The experiments of this work are framed in the field of dried fruit storage and they are carried out with raisins and dried apricots stored for 12 months, in order to compare the outcome of storage in different packaging materials and with different initial internal atmospheres. As a hypothesis, the initial atmosphere and the packaging materials were expected to have a minor influence on the colour evolution compared with the storage temperature.

This paper aims to examine the influence of packaging materials, internal atmosphere and temperature on the colour changes and SO_2 content during storage of dried apricots and raisins packaged both in polypropylene trays thermosealed with different polymeric films and in glass jars. The relation between fruit colour and SO_2 content is also studied. This article builds on previous papers about the package headspace atmosphere changes.

II. MATERIALS AND METHODS

A. Raw Materials

The present research was done with 'Canino' apricots (*Prunus armeniaca*) and 'Moscatel Romano' white grapes (*Vitis vinifera*), harvested in Valencia and Alicante (Spain), respectively. Experiments were carried out with two series of dried apricots and two of raisins, throughout two consecutive harvest seasons. After harvesting, apricots were cut longitudinally into two equal halves and pitted. Grapes were immersed in 0.6% sodium hydroxide solution at 100ºC during 20 s; this cracks the skin and quickens the water loss. Before drying, both apricots and grapes were immersed first in 4% potassium metabisulfite during 35 and 10 min respectively and, then, 5 min in 1% acetic acid solutions (Miranda, Berna, & Mulet, 2019).

B. Drying Processes

The apricots were dried at 50ºC and the raisins at 40ºC, both for 9 h. The product was spread over six metal mesh trays in a single layer, with a maximum total weight of 60 kg. Drying was carried out in a convective dryer equipped with a 2 kW ventilator and resistances with a total of 22 kW. Samples were kept after drying in closed polyethylene bags at 10ºC for 72 h. Before packaging, dried product was mixed thoroughly in order to ensure sample homogeneity.

The products obtained had the following characteristics (results expressed on dry basis):

- Apricots first series: 30.90 $\pm$ 0.17 g water/100 g, 0.904 $\pm$ 0.050 g SO2/kg.
- Apricots second series:
- 27.14$\pm$ 0.01 g water/100 g, 0.62 $\pm$ 0.02 g SO2/kg.
-26.1$\pm$ 0.4 g water/100 g, 0.500 $\pm$ 0.007 g SO2/kg.
- Raisins first series: 17.70 $\pm$ 0.13 g water/100 g, 0.135 $\pm$ 0.007 g SO2/kg.
- Raisins second series: 26.79 $\pm$ 0.01 g water/100 g, 0.370 $\pm$ 0.020 g SO2/kg.

The Codex maximum level for SO2 in apricots is 2.0 g/kg and in raisins is 1.5 g/kg.

C. Packaging

Every series had one set of samples stored in 350 cm^3glass jars with metal twist caps and other sets stored in 500 cm^3 (polypropylene trays supplied by Orved S.L. (Barcelona, Spain) and thermosealed with permeable films supplied by Südpack España S.L. (Barcelona, Spain) and Soplaril Hispania S.A. (Barcelona, Spain). These were:
- Oriented polyamide/polyethylene 15/100: a 15 µm OPA layer with a 100 µm PE layer (Südpack).
- Polyamide/polypropylene 20/75: a 20 µm PA layer with a 75 µm PP layer (Südpack).
- Polyamide/polyethylene 20/70: a 20 µm PA layer with a 70 µm PE layer (Südpack).
- Polyamide/polyethylene 20/75: a 20 µm PA layer with a 75 µm PE layer (Südpack).
- Polyamide/polypropylene 20/50: a 20 µm PA layer with a 50 µm PP layer (Soplaril).

Every package contained 65 ± 10 g of sample. Storage temperatures were: 5, 15, 25 and 40ºC (first series) or 35ºC (second series). The design of the experiments was as follows:
Dried apricots:
– First series: glass and PA/PP 20/50 with air.
– Second series: glass, OPA/PE 15/100 and PA/PP 20/75 with air; OPA/PE 15/100 with nitrogen.

Raisins:
– First series: glass and PA/PE 20/75 with air; glass with nitrogen.
– Second series: glass, PA/PP 20/75 and PA/PE 20/70 with air; PA/PP 20/75 with nitrogen.

Colour coordinates and SO_2 and moisture contents were analysed periodically, throughout the 12 months' storage.

D. Analytical methods

The moisture content was determined in a vacuum oven at 70ºC until achieving constant weight, according to AOAC (1990) Method 934.06. Three replicates were performed for each sample and the mean value was calculated and expressed on dry basis.

The SO_2 content was determined using a method that combined a distillation clean-up in hydrochloric acid with the redox titration by iodine, according to the De Vries, et al. (1986) method. This analysis was replicated twice but, if the results differed more than 15%, a third measurement was done.

The colour was determined with a spectrophotometer Minolta CM-1000 (Tokyo, Japan), set with the D65 light and 10º observation angle and expressed in terms of the 3 CIE Lab colour coordinates. Three replicates were performed and each replicate had 20 pieces. Colour coordinates L*, a* and b* were determined for each sample, corresponding to the CIELAB coordinate system. Colour values are expressed as L*, ranging from 0 (darkness) to +100 (whiteness or brightness), a* (redness to greenness), and b* (yellowness to blueness).

E. Statistical method

This study used a completely randomized design. Data are expressed as means $\pm$ standard deviation (SD). A two-way ANOVA with Student–Newman–Keuls test was performed to assess separately the effects of temperature, packaging material and atmosphere on the moisture, SO_2 content and colour of dried apricots and raisins during 12 months storage. A confidence interval of 95% ($p < 0.05$) was considered to be statistically significant. This analysis was done with Stat graphics Plus v. 5.1 software (Statistical Graphics Corp., Herndon, 2 VA). Multiple Logarithmic Regression Analysis was used to estimate the effect of SO_2 content on fruit colour.

III. RESULTS AND DISCUSSION

A. *Comparison of colour coordinates evolution: effect of temperature*

Figure 1 illustrates the evolution over time of the coordinate L* on the inner and outer side of the fruit for the first series of dried apricots packed in PA/PP 20/50 film, with air as initial atmosphere at 5 and 40ºC. Figures 2 and 3 show the evolution of the coordinates a* and b*, respectively, for these same samples. As observed in these Figures, the evolution of the three colour coordinates is very similar for each temperature. Figure 4 shows the evolution of L* at 15 and 25ºC for these same samples of dried apricots on both sides. From Figures 1 and 4, it can be concluded that, for each temperature, the coordinate L* curves are similar on both the external and internal sides of the dried apricot samples.

Table 1 indicates the results for the evolution of the coordinate L* on the outer side of the second series of dried apricots. Tables 2 and 3 specify the values of the coordinate L* in the two series of raisins.

At a storage temperature of 5ºC, the values of the colour coordinates remain almost constant in the case of the dried apricots. As the temperature increases, the values of the coordinates decrease at a greater rate in the apricots. In the case of raisins, at temperatures of 5 and 15ºC, the colour coordinate L* increases over time, this increase being more accentuated at 5ºC. This could be due to the crystallisation of sugars on the surface of the fruit -"sugaring"-, as will be discussed later. In general, at 25ºC there is a slight decrease in the L* values, which drops even further when the storage temperature is increased to 35 or 40ºC. This seems to indicate that fruit storage temperature is the determining factor for changes in L* values. Accordingly, browning processes, especially as a consequence of the Maillard reactions, could be influenced mainly by the temperature, which could mask the possible secondary effects of other factors, such as type of packaging, packaging atmosphere, and variety of fruit, among others.

Therefore, from Figures 1-5 and Tables 1-3, we conclude that, for each temperature, the coordinates L*, a*, and b* evolve in a very similar way over time in the different packages and under initial packaging atmospheres, both for raisins and the inside and outside of dried apricots. When measuring the darkening of the sample, the coordinate L* seems to be a good indicator of the browning processes, as stated by several authors, for whom there is a significant correlation between the processes generating the colour changes and the evolution of the L* luminosity factor (Bolin & Steele, 1987; Cañellas, Rosselló, Simal, Soler, & Mulet, 1993; Simal, Sánchez, Benedito, & Rosselló, 1999; Joubert, Wium, & Sadie, 2001).

According to Unece (2016) Standard DDP-15, dried apricots may be presented as: whole pitted or unpitted; halves (cut longitudinally into two parts before drying); and slabs, made up of pieces of sound apricots of a colour appropriate to their variety, of irregular shape, size and thickness. Considering this and the results above, the variation in the values of the coordinate L* for the outside of the dried apricots could respond to colour changes produced during storage, as a consequence of processes undergone by these foods. Likewise, these criteria could be extended to raisins, as their analysis can only be carried out on the external side.

B. *Effect of packaging and initial atmosphere*

Since the colour variation may be related to oxidation phenomena, initial packaging atmosphere could be expected to influence colour evolution.

However, as Table 1 demonstrates, the possible effect of the initial packaging atmosphere on the evolution of the coordinate L* has not been observed in dried apricots stored in film OPA/PE 15/100, as the evolution of this coordinate is very similar for both air and nitrogen atmospheres. In this sense, it would be worthwhile checking if the colour evolves in the same way for the different types of packaging used, as might be expected, since these could also affect the composition of the internal atmosphere during the storage period, depending on its different permeability to gases. Table 1 also shows that, for each temperature, the evolution curve of the coordinate L* is very similar for glass and for the different types of films. Statistical analysis of the results indicates that neither the type of packaging nor the initial packaging atmosphere have a very significant influence on the evolution of the coordinate L* ($F < 4.1$ and $p > 0.06$ for packaging; $F < 2.6$ and $p > 0.13$ for atmosphere).

Table 3 shows the evolution of the colour coordinate L* in raisins stored in PA/PP 20/75, PA/PE 20/70, and glass. It is observed that, for each temperature, the values corresponding to film and glass practically overlap, with no significant differences between both containers at all storage temperatures ($F < 4.1$ and $p > 0.05$).

These results coincide with those obtained in a study by Miranda et al. (2019), confirming that the O_2 level in the headspace of polypropylene packages containing dried apricots and raisins, increases during the first months of storage until the outside O_2 concentration is reached, regardless of whether the initial atmosphere is air or nitrogen.

As the moisture content is affected by the type of packaging (Miranda, Berna, González, & Mulet, 2014), which does not have a major influence on the colour coordinate, it can be concluded that colour variations may not have significant link to water losses in food.

C. "Sugaring"

In the two series of raisins analysed, the presence of small white grains was observed, which were produced by the crystallisation of sugars on the fruit surface, a process known as "sugaring". This crystallisation can occur on both the skin and the pulp and can be reversible by gentle heating (Kader, Mitcham, & Crisosto, 1998). This physiological disorder gives rise to a clear loss of acceptability of these products to the final consumer.

Table 3 also shows that the coordinate L* increases during the first weeks of the storage period for the samples kept at the lowest temperatures. Thus, the lower the temperature, the higher the coordinate L* increase during the whole storage period, probably due to the crystallisation of the white sugar granules. It is known that the incidence and severity of browning increase with temperature and time (Kader et al., 1998). In this case, at higher temperatures, the darkening generated by the Maillard processes could hide the white grains, in such a way that L* would remain practically constant at a temperature of 25ºC or may even decrease at higher temperatures (35/40ºC).

D. Relationship between colour and SO_2

Tables 4-6 show the SO_2 content in the second series of dried apricots and the two series of raisins. According to the literature, the rate of browning, especially in the case of dried fruit, is inversely proportional to the SO_2 content of the product (Salunkhe, Do, & Bolin, 1973). Furthermore, adding sulfite to the product, before the drying process, inhibits enzymatic browning during drying and also provides some protection against non-enzymatic browning during storage, while decreasing chemical oxidation (Bolin & Steele, 1987).

Thus, it can be expected that the loss of the SO_2 additive as the storage period progresses will have an influence on the colour coordinate L*. Figure 5 shows the evolution of the SO_2 content and the variation of the colour coordinate L* for the dried apricots stored in PA/PP 20/50 film in air at 5 and 40ºC. In the case of dried apricots, no "sugaring" phenomenon modifies the L* value. Only the two extreme temperatures are shown to visualise the differences more clearly.

It has been observed that, as the SO_2 content decreases, there is a parallel decrease in the values of the coordinate L*, which represents a browning of the sample. This relationship is logical, as the lower the reducing agent content, the more easily the samples are exposed to browning processes (Bolin & Steele, 1987). Since an increase in storage temperature leads to an increase in SO_2 loss (Cañellas et al., 1993; Sanjuán, Bon, Bermejo, Tarrazó, & Mulet, 1996), a parallel decrease in the values of the coordinate L* occurs. The influence of temperature on the variation of the coordinate L* is highly significant ($p < 0.01$), and even more significant on the loss of SO_2 content ($p < 0.001$).

The same trend is observed in all the samples, as shown in Figures 6-9, which demonstrate how the colour coordinate L* varies according to the SO_2 content. These Figures show the results obtained for all the dried apricots and raisins samples, corresponding to the four series analysed under all the storage conditions studied. They show that there is a logarithmic relationship between the colour coordinate L* and the SO_2 content. The two series of dried apricots, with a much higher correlation coefficient, show a significantly better fit. This could be explained by the wider range of SO_2 content values in dried apricots, whose their maximum initial values were 900 and 620 g SO_2/kg, compared to values in both raisin series, 135 and 370 g SO_2/kg, respectively. SO_2 content is higher in the case of apricots, because during the pre-treatment of the halves, the pulp is directly immerse in the sulfite solution and absorbs a higher amount of SO_2 than the skin of raisins. Higher concentrations are often sought in raisins, but are hardly ever obtained in practice. This is because the skin of the raisins is less permeable than the skin of other SO_2 treated fruits such as apricots, pears, and peaches. It is also known that, in the case of raisins, more factors, such as fruit skin integrity, affect colour during drying and storage (Lydakis, Fysarakis, Papadimitriou, & Kolioradakis, 2003). Moreover, the occurrence of sugaring in raisins may also have introduced a greater distortion factor when evaluating the effect of storage conditions on colour variation in raisins.

IV. CONCLUSIONS

Given the relationship between the Maillard reactions and browning, and that these reactions depend critically on temperature, it can be concluded that temperature is the determining factor in the browning processes of dried apricots and raisins found in this study. The other factors, such as initial packaging atmosphere or type of packaging, do not seem to have a significant influence on the changes in colour during the storage of the samples. As storage temperature increases, the browning of the dried apricots and raisins also appears to increase.

As expected, there is a negative correlation between the SO_2 content and the browning of the samples, as this preservative limits or prevents browning reactions from occurring. Therefore, based on the results, it can be concluded that there is a strong relationship between the colour coordinate L* and the SO_2 content. Thus, the lower the SO_2 content, the more Maillard reactions will occur and the fruit will become darker.

Taking into consideration these conclusions, it is highly recommended to treat the fruit with potassium metabisulfite to achieve the maximum content of SO_2 established by the law, in order to limit the browning. The colour coordinate L* is a good indicator of the browning processes. Temperature should not exceed 25ºC to maintain the quality of the product during 12 months. Nevertheless, attention should be paid to the presence and severity of “sugaring” at the lower temperatures. On the other hand, as the different containers do not affect the quality of the fruit, the packaging should be chosen according to market requirements.

REFERENCES

[1.] AOAC International. (1990) Method 934.06 moisture in dried fruits. *Official Methods of the Association of Analytical Chemists*, 15th ed.; AOAC: Virginia, VA, USA.
[2.] Bolin, H.R., & Steele, R.J. (1987). Nonenzymatic browning in dried apples during storage. *Journal of Food Science, 52*(6), 1654-1657.
[3.] https://doi.org/10.1111/j.1365-2621.1987.tb05899.x
[4.] Cañellas, J., Rosselló, C., Simal, S., Soler, L., & Mulet, A. (1993). Storage conditions affect quality of raisins. *Journal of Food Science, 58*(4), 805–809.
[5.] https://doi.org/10.1111/j.1365-2621.1993.tb09363.x
[6.] Chang, S.K., Alasalvar, C., & Shahidi, F. (2016). Review of dried fruits: Phytochemicals, antioxidant efficacies, and health benefits. *Journal of Functional Foods, 21*, 113-132.

https://doi.org/10.1016/j.jff.2015.11.034.

[7.] DeVries, J.W., Ge, H., Ebert, F.J., & Magnuson, J.M. (1986). Analysis for total sulfite in foods by using rapid distillation followed by redox titration. *Journal - Association of Official Analytical Chemists*, *69*(5), 827–830. https://doi.org/10.1093/jaoac/69.5.827

[8.] Driedfruit.net https://www.driedfruit.net/world-dried-fruit-production-metric-tons.html (accessed on 29 October 2021)

[9.] Joubert, E., Wium, G.L., & Sadie, A. (2001). Effect of temperature and fruit-moisture content on discolouration of dried, sulphured Bon Chretien pears during storage. *International Journal of Food Science & Technology*, *36*(1), 99-105.

[10.] https://doi.org/10.1111/j.1365-2621.2001.00412.x

[11.] Kader, A.A., Mitcham E.J., & Crisosto, C. (1998). Dried fruits and nuts: Recommendations for maintaining postharvest quality.

[12.] https://postharvest.ucdavis.edu/Commodity_Resources/Fact_Sheets/Datastores/Fruit_English/?uid=20&ds=798 (accessed on 10 November 2021)

[13.] Link, J.V., Tribuzi, G., & Laurindo, J.B. (2017). Improving quality of dried fruits: a comparison between conductive multi-flash and traditional drying methods*LWT-Food Science and Technology 84*, 717-725. https://doi.org/10.1016/j.lwt.2017.06.045.

[14.] Lydakis, D., Fysarakis, I., Papadimitriou, M., & Kolioradakis, G. (2003). Optimization Study of Sulfur Dioxide Application in Processing of Sultana Raisins. *International Journal of Food Properties*, *6*(3), 393-403. http://doi.org/10.1081/JFP-120020117

[15.] Miranda, G., Berna, À., González, R. and Mulet, A. (2014). The storage of dried apricots: The effect of packaging and temperature on the changes of texture and moisture. *Journal of Food Processing and Preservation* *38*(1), 565–572. https://doi.org/10.1111/jfpp.12004

[16.] Miranda, G., Berna, A., & Mulet, A. (2019). Dried-Fruit Storage: An Analysis of Package Headspace Atmosphere Changes. *Foods*, *8*(2), 56-66.

[17.] https://doi.org/10.3390/foods8020056.

[18.] Rosselló, C., Mulet, A., Simal, S., Torres, A., & Cañellas, J. (1994). Quality of dried apricots: effect of storage temperature, light and SO_2 content. *Journal of the Science of Food and Agriculture*, *65*(1), 121-124. https://doi.org/10.1002/jsfa.2740650118

[19.] Salunkhe, D.K., Do, J.Y., & Bolin, H.R. (1973). Developments in technology and nutritive value of dehydrated fruits, vegetables and their products. *CRC Critical Reviews in Food Technology 4*(2),153-192. https://doi.org/10.1080/10408397309527157

[20.] Sanjuán, N., Bon, J., Bermejo, M.V., Tarrazó, J., & Mulet, A. (1996). Influencia de las condiciones de almacenamiento en la calidad de orejones de albaricoques deshidratados. In E. Ortega, E. Parada, & P. Fito (Eds.), *Anales del I Congreso Iberoamericano de Ingeniería de Alimentos*, *Tomo II* (pp. 312-318).

[21.] Simal, S., Sánchez, E.S., Benedito, J., & Rosselló, C. (1999).Effect of temperature and gas composition on the shelf-life of dehydrated apricots. *Food Science and Technology International*,*5*(5), 377-383. https://doi.org/10.1177/108201329900500502

[22.] UNECE (2016) Standard DDP-15 Concerning the Marketing and Commercial Quality Control of Dried Apricots. Available online:

[23.] https://unece.org/fileadmin/DAM/trade/agr/standard/dry/dry_e/15_DriedApricots_E2016.pdf(accessed on 15 October 2021)

[24.] Waskale, H.S., & Bhong, M.G. (2017). Experimental RGB and CIE Lab Colour Space Analysis and Comparison for Fruits and Vegetables. *Journal of Emerging Technologies and Innovative Research (JETIR)*,*4*, 1-4. https://doi.org/10.6084/m9.jetir.JETIR1704001.

[25.] Weinberg, Z.G., Yan, Y., Chen, Y., Finkelman, S., Ashbell, G., & Navarro, S. (2008). The effect of moisture level on high-moisture maize (*Zea mays L.*) under hermetic storage conditions-in vitro studies. *Journal of Stored Product Research44*(2), 136-144.

[26.] https://doi.org/10.1016/j.jspr.2007.08.006.

[27.] Wu, D., & Sun, D.W. (2013). Colour measurements by computer vision for food quality control -A review. *Trends in Food Science & Technology, 29*(1), 5-20.

[28.] https://doi.org/10.1016/j.tifs.2012.08.004.

[29.] Yadav, A. K., & Singh, S. V. (2014). Osmotic dehydration of fruits and vegetables: a review. *Journal of food science and technology*, *51*(9), 1654-1673. https://doi.org/10.1007/s13197-012-0659-2.

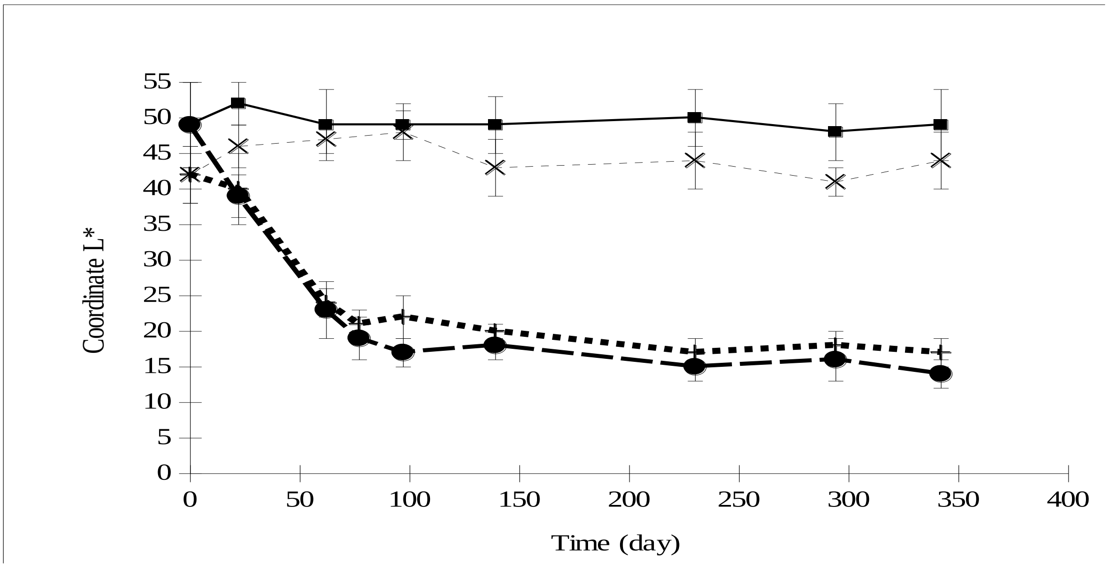

Fig. 1: Evolution of coordinate L* on dried apricots in trays sealed with PA/PP 20/50 film and air stored at 5ºC (inside ■ outside ✕) and 40ºC (inside ● outside +).

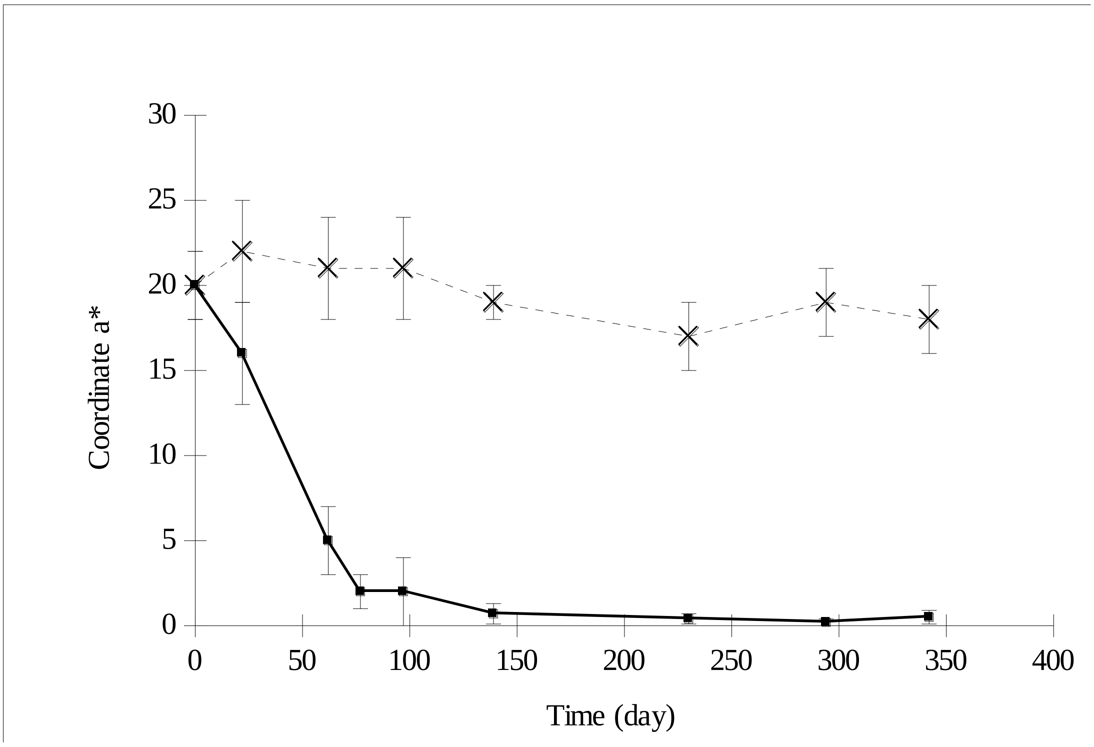

Fig. 2: Evolution of coordinate a* on the outer side of the fruit in trays containing dried apricots sealed with PA/PP 20/50 film and air stored at 5ºC (✕) and 40ºC (■).

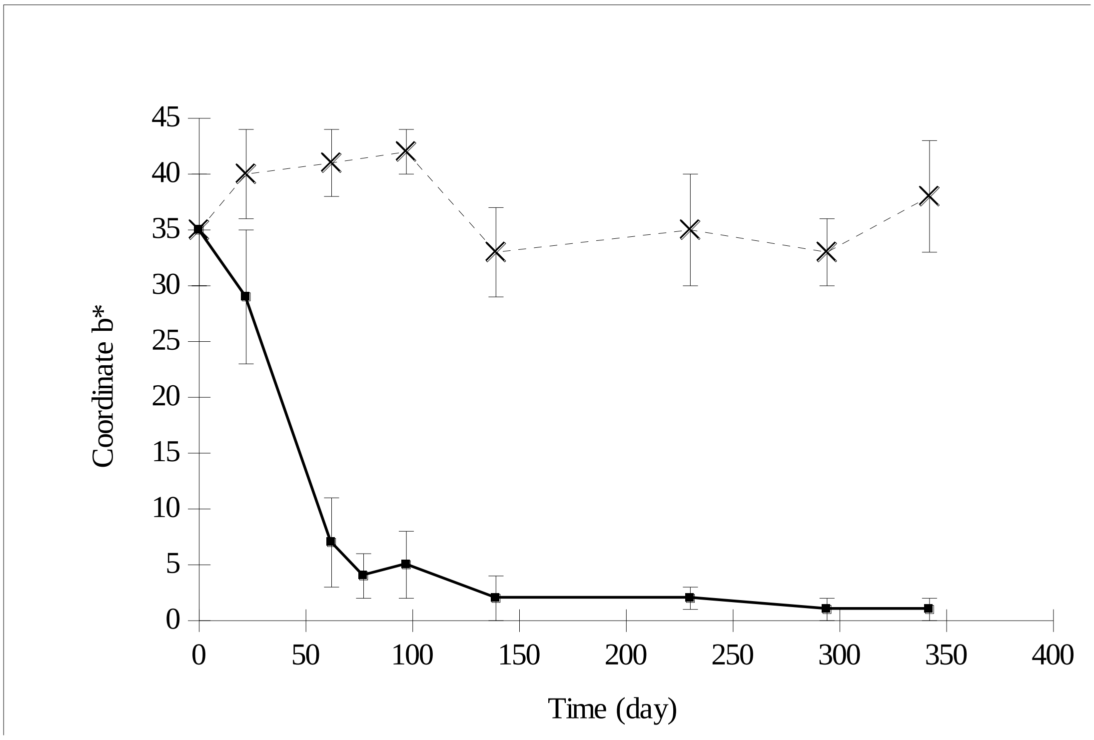

Fig. 3: Evolution of coordinate b* on the outer side of the fruit in trays containing dried apricots sealed with PA/PP 20/50 film and air stored at 5ºC (×) and 40ºC (■).

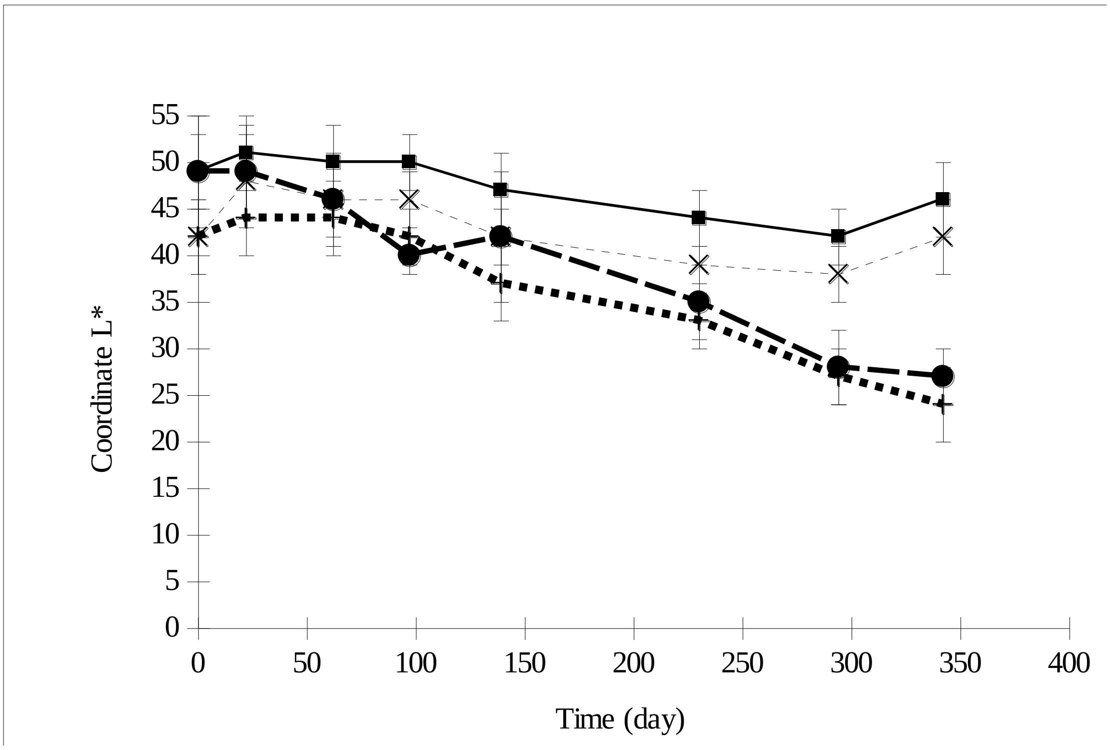

Fig. 4:Evolution of coordinate L* on dried apricots in trays sealed with PA/PP 20/50 film and air stored at 15ºC (inside ■ outside ×) and 25ºC (inside ● outside +).

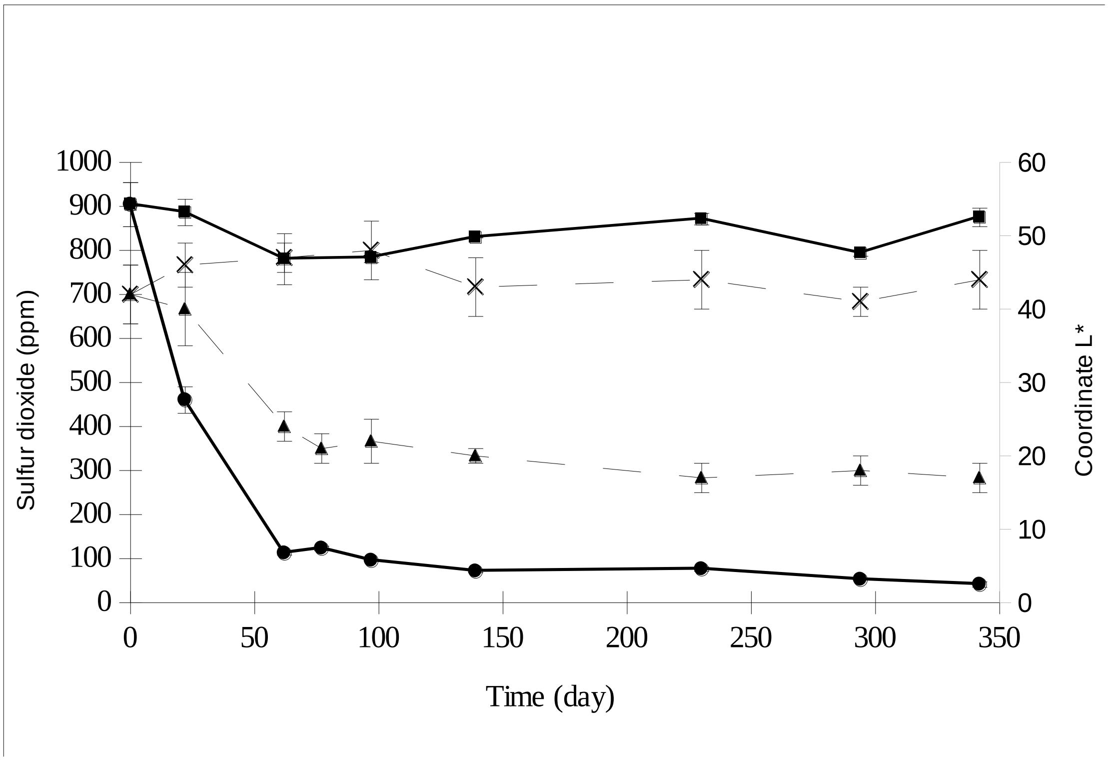

Fig. 5: Evolution of sulfur dioxide and coordinate L* on dried apricots in trays sealed with PA/PP 20/50 film and air stored at 5ºC (■ and ✕) and 40ºC (● and ▲).

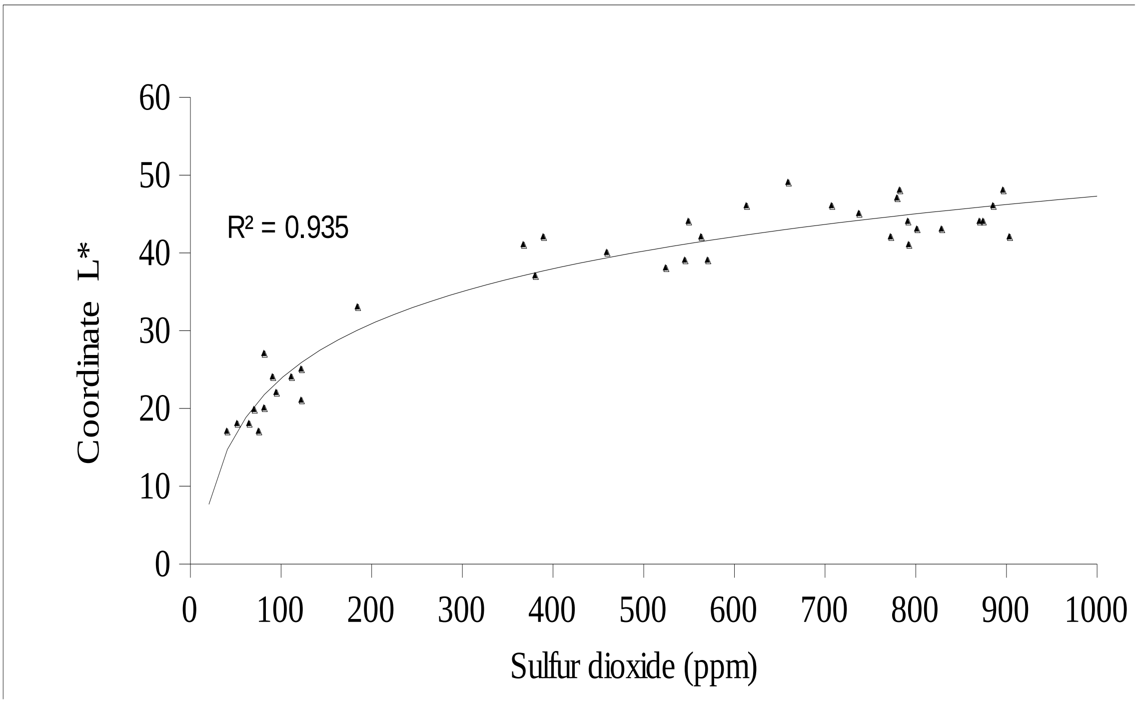

Fig. 6: Coordinate L* vs Sulfur dioxide in all samples of the first series of dried apricots.

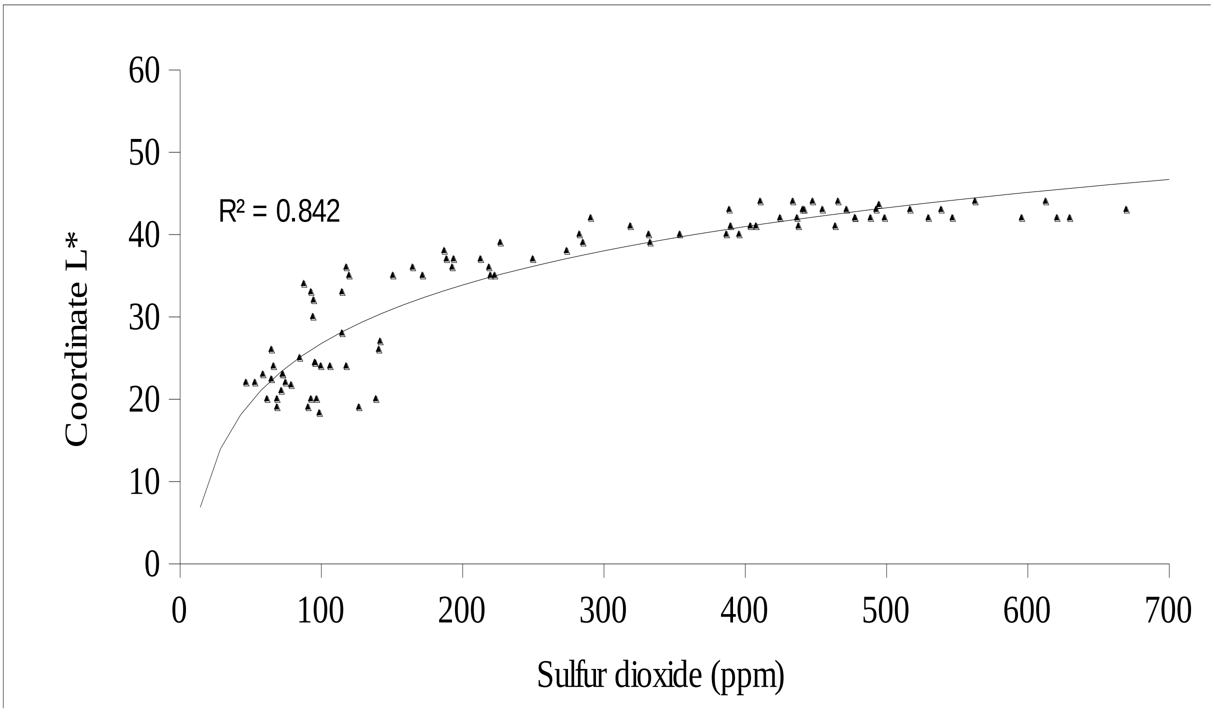

Fig. 7:Coordinate L* vs Sulfur dioxide in all samples of the second series of dried apricots.

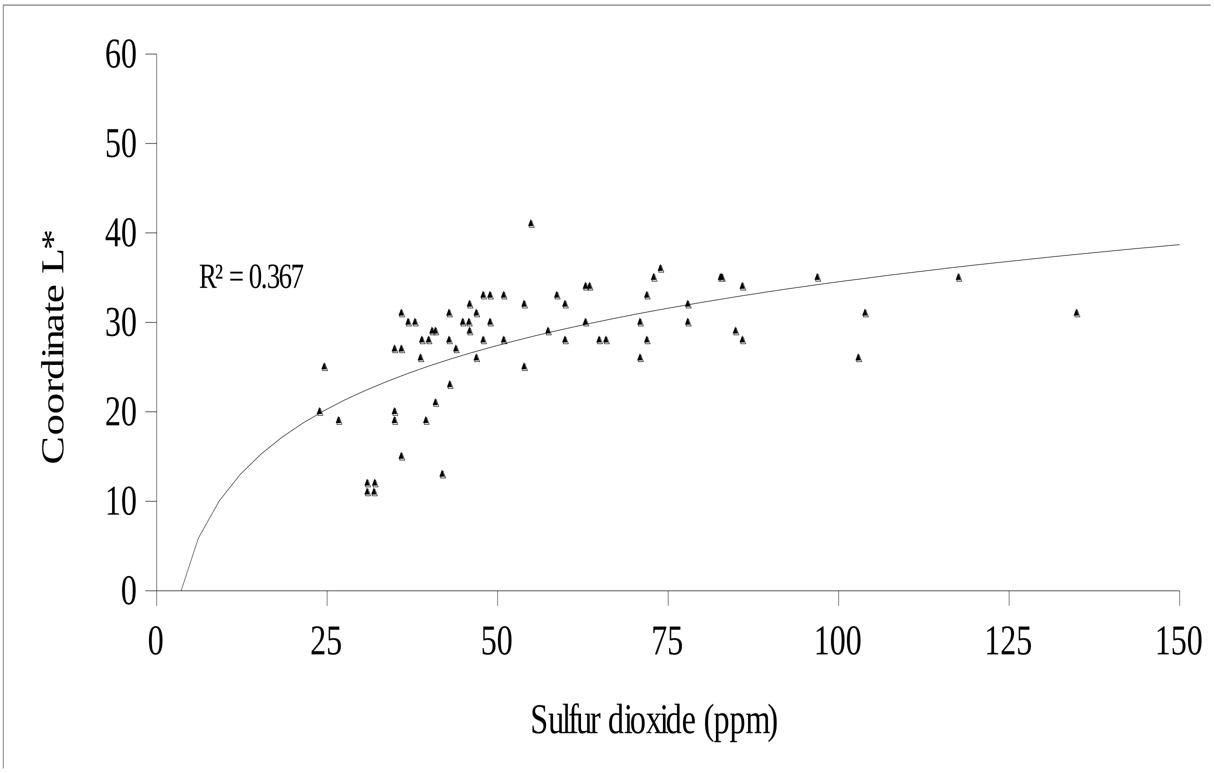

Fig. 8: Coordinate L* vs Sulfur dioxide in all samples of the first series of raisins.

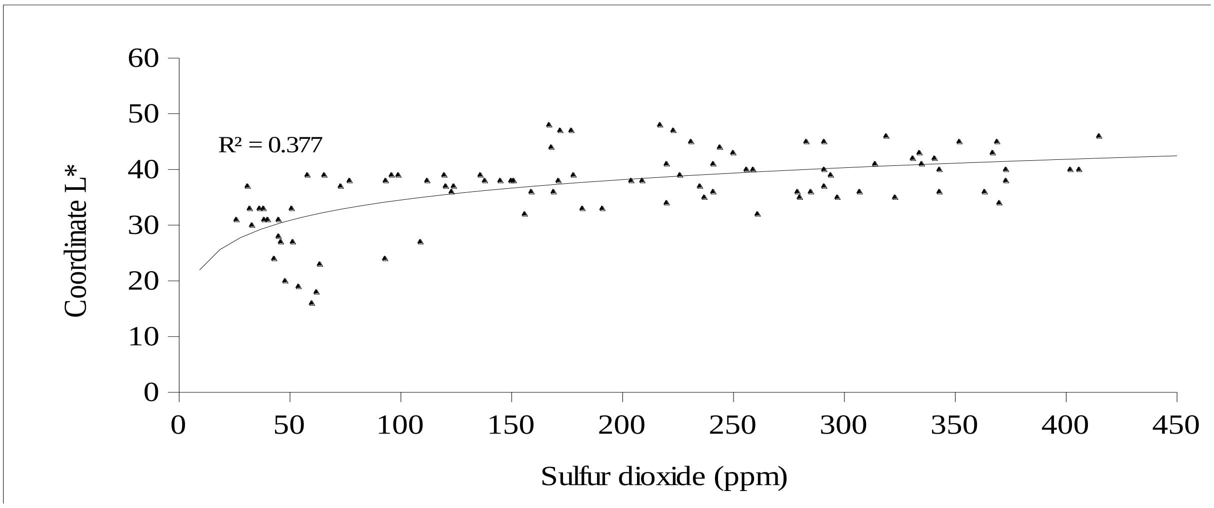

Fig. 9: Coordinate L* vs Sulfur dioxide in all samples of the second series of raisins.

Temp. (ºC)	Package Atm	Coordinate L*												
		0 days	14 days	18 days	66 days	75 days	131 days	157 days	196 days	222 days	243 days	284 days	344 days	354 days
5	0PA/PE 15/100 Nitrogen	42 ± 4	44 ± 4		43 ± 4			42 ± 4		42 ± 3		44 ± 3		41 ± 3
	0PA/PE 15/100 Air	42 ± 4	43 ± 4		43 ± 4			42 ± 3		40 ± 4		43 ± 3		40 ± 3
	Glass Air	42 ± 4	42 ± 4		43 ± 2			43 ± 3		42 ± 2		41 ± 2		44 ± 3
	PA/PP 20/75 Air	42 ± 4		43.6 ± 1.3		42 ± 4	42 ± 5		42 ± 3		41 ± 4		39 ± 4	
15	0PA/PE 15/100 Nitrogen	42 ± 4	42 ± 2		43 ± 4			38 ± 3		36 ± 4		37 ± 2		36 ± 4
	0PA/PE 15/100 Air	42 ± 4	44 ± 4		41 ± 4			40 ± 2		39 ± 4		33 ± 2		35 ± 3
	Glass Air	42 ± 4	43 ± 3		41 ± 4			39 ± 2		35 ± 4		35 ± 4		33 ± 3
	PA/PP 20/75 Air	42 ± 4		41 ± 3		42 ± 3	37 ± 3		38 ± 3		34 ± 2		30 ± 2	
25	0PA/PE 15/100 Nitrogen	42 ± 4	44 ± 4		36 ± 3			27 ± 2		24 ± 3		24 ± 3		22 ± 3
	0PA/PE 15/100 Air	42 ± 4	44 ± 3		37 ± 2			28 ± 2		24 ± 2		21.7 ± 1.4		22.4 ± 1.9
	Glass Air	42 ± 4	43 ± 3		35 ± 2			26 ± 2		24.4 ± 1.7		22 ± 2		23 ± 3
	PA/PP 20/75 Air	42 ± 4		40 ± 3		32 ± 4	26 ± 3		24.4 ± 1.9		22 ± 2		21 ± 2	
35	0PA/PE 15/100 Nitrogen	42 ± 4	40 ± 2		24 ± 3			19 ± 2		19 ± 2		19 ± 2		19 ± 2
	0PA/PE 15/100 Air	42 ± 4	36 ± 3		25 ± 2			20 ± 3		20 ± 3		20 ± 3		20 ± 3
	Glass Air	42 ± 4	37 ± 4		23 ± 2			20 ± 2		20 ± 2		20 ± 2		20 ± 2
	PA/PP 20/75 Air	42 ± 4		35 ± 3		23 ± 3					18.3 ± 1.9			

Table 1: Coordinate L* on the outer side of the second series of dried apricots.

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Temp. (ºC)	**Package Atm**	**Coordinate L***						
		0 days	**35 days**	**71 days**	**121 days**	**179 days**	**240 days**	**335 days**
5	PA/PE 20/75 Air	31 ± 4	26 ± 5	29 ± 6	28 ± 6	30 ± 7	32 ± 9	34 ± 7
	Glass Air	31 ± 4	31 ± 5	31 ± 5	35 ± 6	35 ± 6	36 ± 6	41 ± 5
	Glass Nitrogen	31 ± 4	29 ± 6	31 ± 5	35 ± 8	35 ± 6	34 ± 6	35 ± 10
15	PA/PE 20/75 Air	31 ± 4	28 ± 6	28 ± 5	29 ± 6	28 ± 6	27 ± 4	31 ± 7
	Glass Air	31 ± 4	28 ± 4	34 ± 5	33 ± 5	33 ± 5	33 ± 4	31 ± 4
	Glass Nitrogen	31 ± 4	30 ± 5	32 ± 6	33 ± 6	31 ± 4	30 ± 4	33 ± 6
		0 days	**22 days**	**56 days**	**112 days**	**179 days**	**240 days**	**335 days**
25	PA/PE 20/75 Air	31 ± 4	26 ± 5	28 ± 5	29 ± 5	30 ± 3	27 ± 5	25 ± 4
	Glass Air	31 ± 4	28 ± 4	32 ± 5	30 ± 5	29 ± 4	28 ± 4	27 ± 3
	Glass Nitrogen	31 ± 4	31 ± 6	32 ± 5	29 ± 4	30 ± 3	30 ± 4	28 ± 4
40	PA/PE 20/75 Air	31 ± 4	25 ± 4	23 ± 4	20 ± 3	19 ± 2	20 ± 2	19 ± 2
	Glass Air	31 ± 4	30 ± 5	26 ± 2	19 ± 2	13 ± 2	11 ± 2	11 ± 3
	Glass Nitrogen	31 ± 4	28 ± 4	26 ± 3	21 ± 3	15 ± 2	12 ± 2	12 ± 2

Table 2: Coordinate L* of the first series of raisins.

Temp. (ºC)	Package Atm	Coordinate L*						
		0 days	18 days	75 days	131 days	196 days	257 days	344 days
5	PA/PP 20/75 Nitrogen	34 ± 3	35 ± 3	41 ± 4	43 ± 4	44 ± 2	45 ± 3	45 ± 3
	PA/PP 20/75 Air	34 ± 3	35 ± 4	42 ± 3	45 ± 2	46 ± 3	44 ± 3	47 ± 2
	Glass Air	34 ± 3	37 ± 4	42 ± 3	43 ± 3	46 ± 5	48 ± 3	47 ± 3
	PA/PE 20/70 Air	34 ± 3	35 ± 4	43 ± 4	45 ± 3	45 ± 5	48 ± 3	47 ± 3
15	PA/PP 20/75 Nitrogen	34 ± 3	36 ± 4	41 ± 4	39 ± 4	38 ± 4	38 ± 3	39 ± 4
	PA/PP 20/75 Air	34 ± 3	36 ± 4	41 ± 4	39 ± 4	39 ± 5	39 ± 3	38 ± 3
	Glass Air	34 ± 3	38 ± 3	40 ± 3	41 ± 3	39 ± 5	38 ± 3	38 ± 4
	PA/PE 20/70 Air	34 ± 3	36 ± 4	40 ± 4	40 ± 4	40 ± 4	38 ± 3	39 ± 3
25	PA/PP 20/75 Nitrogen	34 ± 3	36 ± 3	38 ± 2	37 ± 4	37 ± 6	33 ± 4	33 ± 5
	PA/PP 20/75 Air	34 ± 3	34 ± 3	38 ± 3	36 ± 4	36 ± 4	31 ± 4	31 ± 4
	Glass Air	34 ± 3	36 ± 3	37 ± 4	37 ± 4	31 ± 4	31 ± 4	30 ± 4
	PA/PE 20/70 Air	34 ± 3	35 ± 3	38 ± 3	36 ± 4	39 ± 6	37 ± 5	33 ± 5
35	PA/PP 20/75 Nitrogen	34 ± 3	33 ± 2	33 ± 3	27 ± 2	24 ± 4		
	PA/PP 20/75 Air	34 ± 3	33 ± 3	27 ± 2	23 ± 2	18 ± 2		
	Glass Air	34 ± 3	32 ± 2	27 ± 3	20 ± 2	16 ± 1		
	PA/PE 20/70 Air	34 ± 3	32 ± 2	28 ± 3	24 ± 2	19 ± 2		

Table 3: Coordinate L* of the second series of raisins.

Temp. (ºC)	Package Atm	SO₂ ppm (dry basis)												
		0 days	14 days	18 days	66 days	75 days	131 days	157 days	196 days	222 days	243 days	284 days	344 days	354 days
5	0PA/PE 15/100 Nitrogen	621 ± 22	613 ± 16		517 ± 16			630 ± 60		547 ± 20		448 ± 17		404 ± 5
	0PA/PE 15/100 Air	621 ± 22	670 ± 19		441 ± 25			425 ± 11		283 ± 29		389 ± 11		396 ± 16
	Glass Air	621 ± 22	596 ± 12		493 ± 4			539 ± 2		530 ± 4		438 ± 7		411 ± 11
	PA/PP 20/75 Air	499 ± 7		495 ± 45		489 ± 11	437 ± 13		478 ± 12		319 ± 6		333 ± 9	
15	0PA/PE 15/100 Nitrogen	621 ± 22	478 ± 18		442 ± 12			274 ± 26		193 ± 1		194 ± 9		118 ± 6
	0PA/PE 15/100 Air	621 ± 22	563 ± 4		408 ± 22			332 ± 13		285.5 ± 0.2		115 ± 9		120 ± 11
	Glass Air	621 ± 22	455 ± 3		390.0 ± 0.4			227 ± 17		151 ± 19		223 ± 9		93 ± 11
	PA/PP 20/75 Air	499 ± 7		464 ± 3		291 ± 17	250 ± 10		187.3 ± 0.4		88 ± 13		94.4 ± 0.5	
25	0PA/PE 15/100 Nitrogen	621 ± 22	466 ± 13		165 ± 5			142 ± 15		66.5 ± 0.4		118.0 ± 0.3		47 ± 8
	0PA/PE 15/100 Air	621 ± 22	434 ± 3		213 ± 1			115 ± 28		106.5 ± 0.3		79.0 ± 0.4		65 ± 2
	Glass Air	621 ± 22	472 ± 48		172 ± 6			141 ± 13		95.7 ± 0.6		75 ± 9		59 ± 8
	PA/PP 20/75 Air	499 ± 7		354 ± 25		94.9 ± 0.2	65 ± 18		96 ± 9		53.3 ± 0.5		72 ± 9	
35	0PA/PE 15/100 Nitrogen	621 ± 22	387 ± 9		100 ± 2			127 ± 14		69 ± 8				91 ± 1
	0PA/PE 15/100 Air	621 ± 22	219 ± 3		85 ± 3			97 ± 13		61.9 ± 0.2				93 ± 3
	Glass Air	621 ± 22	189 ± 1		73 ± 5			139 ± 18		69 ± 20				
	PA/PP 20/75 Air	499 ± 7		220 ± 23		73 ± 10					99 ± 20			143 ± 29

Table 4: SO_2 content of the second series of dried apricots.

Temp. (°C)	Package Atm	SO$_2$ ppm (dry basis)									
		0 days	**22 days**	**35 days**	**56 days**	**71 days**	**112 days**	**121 days**	**179 days**	**240 days**	**335 days**
5	PA/PE 20/75 Air	135 ± 7		103 ± 8		85 ± 11		66 ± 6	71 ± 2	60 ± 5	63 ± 1
	Glass Air	135 ± 7						97 ± 3	83 ± 12	74 ± 12	55 ± 3
	Glass Nitrogen	135 ± 7						117.7 ± 0.4	82.8 ± 0.0	86 ± 2	73 ± 4
15	PA/PE 20/75 Air	135 ± 7		60 ± 10		65 ± 4		57.5 ± 0.1	48 ± 2	44 ± 3	47 ± 6
	Glass Air	135 ± 7		72 ± 8		63.6 ± 0.0		58.8 ± 0.4	49 ± 2	51 ± 5	36 ± 3
	Glass Nitrogen	135 ± 7		78 ± 1		78 ± 2		72 ± 9	43 ± 9	45.9 ± 0.1	48 ± 1
25	PA/PE 20/75 Air	135 ± 7	71 ± 6		39 ± 4		41 ± 2		38 ± 8	35 ± 3	24.7 ± 0.7
	Glass Air	135 ± 7	86 ± 7		54 ± 9		37 ± 2		40.5 ± 0.7	43 ± 7	36 ± 1
	Glass Nitrogen	135 ± 7	104 ± 6		46 ± 4		46 ± 10		49 ± 5	45 ± 2	40 ± 3
40	PA/PE 20/75 Air	135 ± 7	54 ± 8		43.1 ± 0.3		35 ± 4		26.8 ± 0.0	24 ± 1	39.6 ± 0.4
	Glass Air	135 ± 7	63 ± 12		47 ± 6		35 ± 1		42 ± 2	32 ± 2	31 ± 2
	Glass Nitrogen	135 ± 7	51 ± 4		38.8 ± 0.1		41 ± 1		36 ± 2	32.1 ± 0.6	31 ± 1

Table 5: SO$_2$ content of the first series of raisins.

Temp. (ºC)	**Package Atm**	**SO_2 ppm (dry basis)**						
		0 days	**18 days**	**75 days**	**131 days**	**196 days**	**257 days**	**344 days**
5	PA/PP 20/75 Nitrogen	370 ± 21	297 ± 27	314 ± 20	367 ± 8	244 ± 1	231 ± 11	291 ± 11
	PA/PP 20/75 Air	370 ± 21	323 ± 11	340.8 ± 0.5	369 ± 20	415 ± 8	168 ± 12	223 ± 11
	Glass Air	370 ± 21	291 ± 5	331 ± 20	250 ± 19	319 ± 11	167 ± 20	177 ± 9
	PA/PE 20/70 Air	370 ± 21	237 ± 7	334 ± 29	352 ± 11	283 ± 17	217 ± 9	172 ± 2
15	PA/PP 20/75 Nitrogen	370 ± 21	307 ± 61	335 ± 10	294 ± 12	209 ± 9	149.9 ± 0.2	99 ± 9
	PA/PP 20/75 Air	370 ± 21	343 ± 64	241 ± 29	178 ± 9	65.6 ± 0.2	58 ± 6	112 ± 10
	Glass Air	370 ± 21	373 ± 45	373 ± 21	220 ± 10	226 ± 12	145 ± 11	93.3 ± 0.4
	PA/PE 20/70 Air	370 ± 21	279 ± 27	402 ± 43	291 ± 18	259 ± 9	77 ± 11	119.7 ± 0.5
25	PA/PP 20/75 Nitrogen	370 ± 21	169 ± 3	138 ± 9	124 ± 9	73 ± 9	32 ± 10	38.2 ± 0.2
	PA/PP 20/75 Air	370 ± 21	220 ± 22	151 ± 9	123 ± 10	159 ± 1	38.5 ± 0.9	45 ± 8
	Glass Air	370 ± 21	363.4 ± 0.6	235 ± 6	120.4 ± 0.0	40.1 ± 0.0	26 ± 1	33 ± 10
	PA/PE 20/70 Air	370 ± 21	280 ± 36	204 ± 10	241 ± 9	96 ± 8	31 ± 8	50.9 ± 0.0
35	PA/PP 20/75 Nitrogen	370 ± 21	182 ± 32	36.4 ± 0.2	51.4 ± 0.0	93 ± 8		36 ± 17
	PA/PP 20/75 Air	370 ± 21	191 ± 7	46 ± 9	63.6 ± 0.2	62.1 ± 0.1		30 ± 8
	Glass Air	370 ± 21	261 ± 2	109 ± 19	48 ± 29	60 ± 9		39.9 ± 0.1
	PA/PE 20/70 Air	370 ± 21	156 ± 15	45 ± 9	43 ± 9	54 ± 8		28 ± 7

Table 6: SO_2 content of the second series of raisins.