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Effects of Tray-Drying on the Physicochemical, Microbiological, Proximate, and Sensory Properties of White- and Red-Fleshed Loquat (*Eriobotrya Japonica* Lindl.) Fruit

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Abstract: Loquat fruits, highly valued by consumers for their characteristic aroma and pleasant taste, have a short post-harvest life and are susceptible to mechanical damage, loss of firmness, and initial organoleptic characteristics. The aim of this work was to develop a drying method suitable for storing loquat fruits in polyamide/polyethylene (PA/PE) bags containing two gaseous mixtures (treatments): $MAPN_2$ (100% N_2) and MAPP (21% O_2 and 0.04% CO_2), at room temperature (20 ± 1 °C) for at least 2 months. The effects of these conditions on the physico-chemical, microbiological, proximate, and sensory properties of fruit stored over a 50-day time interval were studied. The results showed that convective tray dehydration treatment at 70° for 12 h had good drying efficiency for loquat slices. In addition, the $MAPN_2$ packaging limited the browning of the slices, keeping the microbial groups below the detection limits, with a clear positive effect on some minerals and vitamins, which were higher in concentration compared to the MAPP-packed samples. From an applicative point of view, the tray drying method for loquat fruits is useful on a small scale but could also be easily industrialized.

Keywords: loquat; dried fruit; modified atmosphere packaging; fruit quality; food safety; vitamins; minerals; sensory analysis

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1. Introduction

Loquat (*Eriobotrya Japonica* Lindl.) is a subtropical evergreen fruit tree belonging to the Rosaceae family originating from southeastern China. Nowadays, loquat is cultivated in areas between the 25th parallel south and the 38th parallel north in more than 30 countries across the globe. World production is estimated to be close to 200,000 tons, concentrated in China, Japan, Pakistan, Mediterranean countries (Spain, Algeria, Turkey, Cyprus, Egypt, Greece, Tunisia Israel, and Italy), and to a lesser extent Portugal, India, Brazil, Chile, and the United States.

Loquat was introduced to Italy at the beginning of the 19th century [1] and spread out into several countries, adapting to subtropical and temperate climates in the same areas where citrus can be grown [2]. In Italy, according to latest available data, loquat is cultivated almost completely on the northern coast of Sicily, especially in Palermo Province, where an area of 400 hectares and a harvested production of 4843 tons represent, respectively, 72.8% and 81.8% of Italian loquat production [3]. Here, loquat blooms in fall and early winter, and its white flowers give birth to spherical-oval red or white-fleshed pomes during late spring and early summer [4]. Loquat fruits are very aromatic with a pleasant taste [5], are a remarkable source of antioxidant phytochemicals, and may have chemopreventive effects at dietary amounts [6]. On the other hand, loquat fruit has a very short postharvest

life and is sensitive to loss of moisture and firmness, mechanical and physical damage, and microbial decay [7]. Low-temperature storage is the most diffused method to extend postharvest life, but a large part of the cultivars are severely affected by chilling injuries during cold storage. Tissue leatheriness, internal browning, and lignin accumulation are major disorders. Furthermore, several fungal pathogens in many grown areas, including *Alternaria alternata*, *Aspergillus niger*, *Botrytis cinerea*, *Colletotrichum gloeosporioides*, *Curlaria lunata*, *Diplocarpon mespili*, *Diplodia natalensis*, *Diplodia seriata*, *Geotrichum candidum*, *Fusarium solani*, *Mucor fragilis*, *Pestalotia* sp., *Phytophthora palmivora*, *Spilocaea pyracanthae*, and *Fusicladium eriobotrye*, infest loquat [8,9]. The fruit is also subject to several physiological disorders, such as purple spot and russeting, that cause the loss of commercial value by affecting the visual appearance in many areas where loquat is grown [10,11]. The development of these chilling-related diseases and disorders limits loquat storage life and reduces consumer acceptance of this fruit. Hence, processing into jam, juice, canned or dried fruit, etc. can increase loquat shelf life and economic value compared to its fresh/unprocessed form [12]. Processing not only adds value, but increases returns on produce as well. It further increases market opportunities and improves shelf life to tackle seasonality and perishability [13].

Drying is probably one of the oldest methods of food preservation. Drying consists of the removal of water to a final concentration, which assures microbial stability and guarantees expected shelf-life of the product [14]. The aim of this process is to obtain the best quality attributes of the product, and it is related to how it will be used. Drying occurs through the vaporization of liquid by supplying heat to whole fruit, fruit chips, or pieces/slices by conduction (contact or indirect dryers), convection (direct dryers), radiation, microwave, or radio frequency electromagnetic methods. There are different single or combined drying methods applied to different varieties of fruits under different preservative solution, and with different effects on drying kinetics and quality parameters. Sun dried fruits and fruit products are the best known of all dried foods. Conventional open sun drying permits a product with good qualitative traits, but it is subject to environmental contamination and the process is slow. Hot air drying is an alternative method that decreases dehydrating time and improves the quality of the final product. There are many dryers used in domestic and industrial application such as spray dryers, freeze dryers, vacuum dryers, fluidized bed dryers, tray dryers, etc. This last one is the most used for fruit because of its easy and economic design [15], using a hot air stream across the whole chamber with forced circulation to dry the fruit. Moreover, tray drying increases the shelf-life of the fruit, reduces packaging cost, allows lower shipping weights with environmental advantages, and reduces fruit waste (market-rejected fruit), while offering a new fruit-derived product.

Tray drying application on the most cultivated tropical fruit such as banana [16], mango [17], papaya [18] and pineapple [19] has been recently studied. To date, only a few studies have been conducted on loquat concerning the application of different drying technologies on fruit texture and antioxidants [20], chemical and microstructural properties [21], carotenoids, and volatile compounds [22], or on the development of mathematical models [23,24]. Therefore, the influence of tray drying in loquat and the quality properties of the obtained product are not well acknowledged. The temperature of the drying air is one of the principal parameters of this process, since it influences the drying kinetics and the physicochemical properties of the dry product [16]. Changes in structure occur during drying process depending on the composition and nature of the fruit and the drying technique, influencing the fruit's physical-chemical and sensory properties [21]. Shrinkage and shape distortions, browning, fading of natural color or discoloration, decreased flavor, gumminess, or juiciness are the most undesirable effects of drying [14]. Inactivation of enzymes is necessary to cease such oxidation reactions and prevent browning. For this purpose, loquat fruit has been preserved with sodium bisulfite, sodium benzoate, and potassium metabisulphite to avoid enzymatic browning [20,21,23]. However, there is an increasing consumer demand for natural products with anti-browning compounds [25].

Among the natural anti-browning agents extensively used to control browning citric acid and ascorbic acid are weak organic acids found in fresh fruits and vegetables [26]. The use of these compounds would be of indubitable importance for more widespread consumer acceptance of dried products. Actually, the drying of fruit on a commercial scale has received a resurgence of interest during the past years considering the importance of these products to human health [27,28]. The potential industrial uses of dried fruit snacks and their by-products include their use as an ingredient in bakery and confectionery products or as additives to several cereal-based products, yogurts, and cheeses.

Thus, the objective of this work was to set up a tray drying method for red- and white-fleshed loquat fruit and investigate the influence of the drying on the fruit's physico-chemical, proximate, microbiological, and sensory properties, analyzing a long period of storage. Therefore, we studied different air drying temperatures to determine the best drying condition for loquat slice production, and examined the behavior of slice over 50 days of storage in passive and modified atmosphere packaging (MAP). The practical applications are to develop a simple and low-cost convective drying method that could be widely used in fruit loquat processing and in small/large scale manufacturing to obtain a new product characterized by a high shelf life.

2. Materials and Methods

2.1. Vegetal Material

Ripe loquat fruits (*Eriobotrya japonica* L.) at the stage 809 on the BBCH scale [29], ripe for consumption with typical taste and firmness, were used. Ripe fruit was used to prevent the waste of produce through the application of hot air dehydration. We selected white-fleshed fruit (Cv. Claudia) and red-fleshed fruit (Cv. Peluche) grown in Sicily. Both red- and white-fleshed cultivars presented a high percentage of damaged fruit with spots on the fruit. Consequently, part of the yield fetches a very low price on the market (about 1€) because of its damaged appearance [30], and drying could valorize this production. Fruit was harvested in a commercial orchard located in the village of S. Maria di Gesù, Palermo (Sicily, Italy; 38°04′ N, 13°22′ E, 150 m a.s.l.) from adult trees spaced 5 × 5 m and cultivated according to the protocols of organic agriculture. Twenty kilograms of fruits (fruit average weight 54 ± 7.7 g) were hand-picked randomly from 10 trees using skin color as harvest index [22].

2.2. Experimental Design

Different preliminary tests on loquat fruit dehydration were carried out with the aim of finding the right time/temperature combination and whether to dehydrate the fruit with or without its skin. For this reason, the initial experimental protocol involved the use of two different dehydration temperatures (applied to both cultivars with and without skin):

- Thesis 1: dehydration at 50 °C for 12 h;
- Thesis 2: dehydration at 70 °C for 12 h.

Raw fruits were washed with distilled water (5 °C) and sanitized in 200 $\mu L \cdot L^{-1}$ Ox-Virin (solution of hydrogen peroxide and peroxyacetic acid; 0.5% w/v) for 10 min. Subsequently, the fruits were peeled, seeded, and cut in half longitudinally with a curved knife obtaining two slices. Then, the slices were treated using the dipping technique [31] with an antioxidant solution to prevent browning, which contained citric acid and ascorbic acid, natural anti-browning agents, in concentrations of 0.5 g/0.5 L of distilled water, for 5 min. A tray dryer (Ausla, 1000 watt, Italy) was used to dry the fruit for 12 h at the selected temperature.

The dehydrated fruits were stored by modified atmosphere packaging (MAP) technology, in polyamide/polyethylene (PA/PE) bags, with either a mixture containing 100% N_2 (MAP N_2) or in passive-MAP conditions (MAP P–21% O_2 and 0.04% CO_2) at room temperature (20 ± 1 °C) for 50 days.

Analyses were carried out every 10 days (T_{10}; T_{20}; T_{30}; T_{40}; T_{50}) and samples were divided as follows: 200 g of dehydrated loquat slices per bag × 3 bags for treatments × 5 storage times, for each cultivar.

Loquat slices were stored using PA/PE bags composed at PA 80%-PE 20%, 90 µm in thickness and 500 cm^3 in volume, with an oxygen permeability of 47.6 $cm^2/(m^2$ day atm) and a water vapor transmission rate of 3.9 $g/(m^2$ day atm) [32].

Modified atmosphere was obtained inside the sealed bags using a digitally controlled packaging machine (VM 16 Orved S.p.A, Musile di Piave, Venezia, Italy).

The treatments were as follows:

1. $MAPN_2$ white-flesh cultivar;
2. $MAPN_2$ red-fleshed cultivar;
3. MAPP white-fleshed cultivar;
4. MAPP red-fleshed cultivar.

2.3. Physico-Chemical Analysis

Fruit weight, longitudinal diameter, transverse diameter, color, firmness, total soluble solids content, and titratable acidity were analyzed on a sample of 30 raw fruits per cultivars.

Fresh weight (FW-g) was measured with a precision electronic scale (Gibertini EU-C 2002 RS, Novate Milanese, Italy), while the fruit longitudinal diameter (LD-mm) and fruit transverse diameter (TD-mm) was measured with a digital caliper (Turoni TR53307, Forlì, Italy). Color of fruit slices was determined on basis of CIE $L^*a^*b^*$ color system (CIE $L^*a^*b^*$: lightness (L^*); redness/greenness (a^*); yellowness/blueness (b^*); chroma (C^*); Hueangle (h°) measured using a digital colorimeter (CR-400 Chroma Meter, Minolta, Japan). Calibration of the color meter was performed against a white tile background (Illuminants C: Y $\frac{1}{4}$ 89.53, x $\frac{1}{4}$ 0.3247, y $\frac{1}{4}$ 0.3198) prior to each measurement.

For each slice, color parameters (L^*, a^*, and b^*) were measured and means of all measurements were determined for each package.

The color differences (ΔE) between the colors at each evaluation time for the fruit slices of each cultivar and the color of the fruit slice were measured at T_0, following the Equation (1):

$$\Delta E = (L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2 \quad (1)$$

where L^*_0, a^*_0, and b^*_0 represent the values of the color parameters measured after dehydration of the loquat slices.

Chroma (C^*) values, which indicate the quantitative attribute of color intensity, and hue angles (h°), which are considered as the qualitative attribute of color of samples, were calculated using Equations (2) and (3), respectively:

$$C^* = \left(a^{*2} + b^{*2}\right)^{\frac{1}{2}} \quad (2)$$

$$h^\circ = \arctan\left(\frac{b^*}{a^*}\right) \quad (3)$$

The firmness of the slices was measured using a durometer (Durofel Agrosta 100Field, Serqueux, France) and converted to Newtons using Equation (4) [33]:

$$N = 9.8\left(e^{\frac{Durofel - 59.32}{14.89}}\right) \quad (4)$$

Total soluble solids content (TSSC Brix) was measured by a digital refractometer (Atago, Tokyo, Japan) and expressed as °Brix, and titratable acidity (TA g/L) were measured using a pH meter-titrator (Titromatic 1S, Crison, Barcelona, Spain) and expressed as grams of malic acid per liters of crude loquat juice (g L^{-1} malic acid) and was determined by titration to an end point of pH 8.2 using 5 mL of juice diluted with 10 mL distilled water.

The dried fruit slices were checked for drying efficiency (DR%), which was calculated using Equation (5) [34]:

$$\%DR = \frac{(c-a)}{(b-a)} \times 100 \quad (5)$$

a = weight of the empty tray;
b = weight of the tray with the product before drying;
c = weight of the tray with the product after drying.

After dehydration and before packing in MAP, on a representative sample of 30 pieces of fruit, both for Claudia and Peluche cultivars, the following parameters were assessed for all treatments:

- Color;
- Firmness (N);
- Longitudinal Diameter;
- Transverse Diameter.

while the fruit length—longitudinal diameter (mm), and fruit width—transverse diameter (mm) with a digital caliper.

Analyses were presented as mean ± standard deviation (SD) of ten replicates. These analyses were repeated at 10-day intervals for a period of 50 days of storage at room temperature (20 ± 1 °C) after opening the bags.

2.4. Microbial Analysis

Ten grams of fresh and dehydrated sliced loquat samples from each cultivar and treatment were transferred into a sterile stomacher bag (BagLight 400, Interscience, Saint Nom, France) added with 90 mL of Ringer's solution (Sigma-Aldrich, Milan, Italy) and homogenized in a BagMixer 400 (Interscience) for 3 min at the highest speed. Homogenized samples were then serially diluted (1:10) and the cell suspensions were used for the search of the main microbial groups belonging spoilage and pathogenic populations by plate count following the approach of Passafiume et al., 2021 [35]. Briefly, total mesophilic microorganisms (TMM) and total psychotrophic microorganisms (TPM) were detected on plate count agar (PCA), *Pseudomonas* spp. on *Pseudomonas* agar base (PAB) added with fucidin cephaloridine supplement (CFC), members of the *Enterobacteriaceae* family on violet red bile glucose agar (VRBGA), yeasts and molds on yeast extract peptone dextrose (YPD) agar supplemented with chloramphenicol (0.1 g/L) to prevent bacterial growth, *Listeria* spp. on *Listeria* selective agar base with SR0140E supplement, and *Salmonella* spp. and *Escherichia coli* on Hektoen enteric agar (HEA). All plate counts were performed by spreading, except those for Enterobacteriaceae, which were performed by pouring VRBGA plated by pour plate [36]. All media were purchased from Microbiol Diagnostici (Uta, Italy). Microbiological analyses were performed in duplicate.

2.5. Proximate Composition

The ascorbic acid (Vitamin C) and the retinol (Vitamin A) were determined according to procedures previously described by Barros et al., 2007 [37]. For this determination, the dried methanolic extract (100 mg) was extracted with 10 mL of 1% metaphosphoric acid for 45 min at room temperature and filtered through Whatman no. 4 filter paper. The filtrate (1 mL) was mixed with 9 mL of 2.6–dichlorophenolindophenol and the absorbance was measured within 30 min at 515 nm against a blank. Vitamin C and Vitamin A were calculated on the basis of the calibration curve of authentic L-ascorbic acid (0.02–0.12 mg/100 g). The contents of Ca, Mg, K, Na, and P were determined using atomic absorption spectroscopy following wet mineralization, while P was determined using a colorimetric method [38]. All measurements were done in three replicates.

2.6. Sensory Evaluation

Sensory evaluation was performed by a team of 30 judges (sixteen men and fourteen women aged between 20 and 60 years) with a good background and knowledge of the details of this kind of food evaluation [39], following the guidelines of UNI 10957:2003 legislation [40]. During the preliminary meetings, 14 qualitative descriptors were chosen for the definition of the sensory profile, generated based on citation frequency (>60%) and listed below: visual appearance (VA); color (CL); browning (BR); loquat odor (OL); honey odor (OH); off-odor (OO); crispness (FF); softness (GM); juiciness (JUI); loquat flavor (FL); caramel flavor (FC); sweetness (SW); acidity (AC); and sourness (SO).

The evaluation was carried out from 10.00 a.m. to 12.00 p.m. in a room under white lights. Each panelist received in random order a sample of three fruit slices for each cultivar and each treatment, and water was provided for rinsing the mouth between each sample.

The judges evaluated the intensity of each descriptor by assigning a score between 1 and 9, where each score represented a different level of intensity of the quality descriptors. The panelists assigned scores to the descriptors according to the nine-point intensity scale: 1—no sensation, 2—barely recognizable, 3—very weak, 4—weak, 5—light, 6—moderate, 7—intense, 8—very intense, and 9—extremely intense [3].

Statistical Analysis

Using R software (R Core Team, 2013), repeated measures ANOVA and Bonferroni-adjusted pairwise *t*-tests ($p \leq 0.05$) were carried out for all studied parameters in order to assess significant differences between the means of the treatments.

3. Results and Discussion

3.1. Fresh Fruit

Before proceeding with the dehydration of the loquat fruits, chemical-physical characterization of the samples was carried out on 30 raw fruits for both cultivars. By commercial classification, that is, based on the transverse diameter of the fruits [41] (classes: GGG > 53 mm, GG: 46–52 mm, G: 32–45 mm and M: 31–28 mm), the fruits of both cultivars belong to the commercial category G.

The results of the color study (Table 1) show that the brightness (L^*) of the pulp is higher in white-fleshed fruit (Claudia) than in yellow-fleshed fruit (Peluche), reflecting the more intense color, which depends on the higher accumulation of carotenoids [42]. The a^* (redness/greenness) and b^* (yellowness/blueness) values were much greater in Peluche. Alternatively, the color was well-described by h° as follows: 0° for red-purple and 90° for yellow [43]. Therefore, with hue angles of 1.14° and 0.96°, the peel color of white-fleshed and red-fleshed cultivars tends to be yellow and orange, respectively.

Table 1. Values of CIE $L^*a^*b^*$ coordinates measuring both cultivars, with values of chroma and hue angle (lightness (L^*); redness (a^*); yellowness (b^*); chroma (C^*); hue angle (h). Data correspond to the means ± SD.

Cultivars	L^*	a^*	b^*	C^*	h°
Claudia	66.01 ± 0.19	11.20 ± 0.21	24.49 ± 0.23	26.75 ± 0.33	77.20 ± 4.62
Peluche	60.00 ± 0.17	24.60 ± 0.09	35.00 ± 0.29	42.78 ± 0.61	70.85 ± 3.18

Table 2 shows the results of the physico-chemical analysis of both cultivars. Peluche shows a higher content of TSSC than Claudia. The cultivar 'Claudia' shows the highest consistency. These data are similar to that reported by Insero et al., 1993, for loquat fruits of the same cultivars grown in Palermo [44]. Both cultivars showed similar values to the TSSC observed by Xu and Chen, 2011 [45] and Hasegawa et al., 2010 [46]. Finally, the cultivar Peluche reached the highest level of the TSSC/TA ratio, which indicates a sweeter fruit [3,6].

Table 2. Values of TSSC (total soluble solids content, Brix); TA (titratable acidity, g L^{-1} malic acid); TSSC/TA ratio; FF (firmness; N) measured on both cultivars. Values represented as mean ± SD.

Cultivars	TSSC	TA	TSSC/TA	FF
Claudia	9.11 ± 0.16	0.69 ± 0.07	13.20	30.90 ± 0.18
Peluche	12.33 ± 0.21	0.82 ± 0.09	15.04	25.00 ± 0.22

3.2. Preliminary Test

Table 3 refers to the preliminary test carried out in order to choose the best "time-temperature" combination to obtain a high-quality dehydrated product. The best maintains the organoleptic and nutritional characteristics of the fresh fruit. The principle of dehydration is to reduce water content to increase the shelf-life of the product [47]. Our data show that the value of the DR% is about 40%, after a period of dehydration at 50 °C for 12 h. The fruits of both cultivars were particularly browned, as can be seen from the colorimetric values (Table 3), and gummy to the touch, characteristics not appreciated by consumers in dehydrated products [48]. The enzymatic browning could be due to the destruction of carotenoids, as reported by Mazzaglia et al., 2020 [40]. For this reason, the treatment at 50 °C for 12 h was not applied and we proceeded only with the application of a hot air dehydration treatment at a temperature of 70 °C for 12 h, which also gave the best results in chemical-physical parameters in the preliminary test (data not shown).

Table 3. Results of the analyses of CIE *L*a*b** coordinates, with values of chroma (C*), hue angle (h°), color variation (ΔE), and drying efficiency (DR%). Values represented as mean ± SD.

Time-Temperature Combination	*L**	*a**	*b**	*C**	h°	ΔE	DR%
50 °C for 12 h	46.04 ± 0.22	12.95 ± 0.19	39 ± 0.24	40.90 ± 0.10	1.24 ± 0.21	14 ± 0.03	39.07 ± 0.15

3.3. Longitudinal and Transverse Diameter and Dry Residue (DR%)

Concerning the Claudia Cv., as shown in Figures 1 and 2, the longitudinal diameter (LD) and the transverse diameter (TD) decreased with the dehydration process. In particular, before dehydration, the loquat slices had a LD of 50.59 mm and a TD of 43.04 mm. After dehydration, the values decreased to 35.22 and 32.70 mm, respectively. Thus, the dehydration process reduced the LD of loquat slices by 15.37 mm and the TD by 10.34 mm. Comparing these data with DR% showed a water content loss of 87.08%. After 50 days of storage, the LD was further reduced by 9.41 mm and the TD by 8.07 mm in MAP N_2-treated slices, while MAP P-treated slices were reduced in diameters (LD and TD) by 7.75 and 6.86 mm, respectively. Thus, dehydrated white-flesh loquat treated with MAP P lost more water content at the end of the storage period; in fact, their diameter decreased more than the fruits treated with MAP N_2.

For Peluche Cv, the LD before dehydration was 48.93 mm, while the TD was 44.12 mm. After dehydration, these values decreased to 36.65 and 31.95 mm, respectively, reducing by about 12 mm. Thus, after dehydration, loquat slices lost 87.17% of their DR%. However, the differences between the MAP N_2 and MAP P treatments, detected over up to 50 days of storage, were as follows: the data from the MAP N_2 treatment showed that the LD decreased by a further 11.62 mm, while the TD decreased by a further 9.86 mm, whereas the LD of MAP P lost 9.16 mm and the TD lost 8.16 mm. Therefore, according to these data, the best treatment seems to have been MAP N_2, probably due to the N_2 inside the bags. In fact, according to different studies [39,49,50], the N_2 alone or in combination with other gases seems to improve the shelf-life of the fruit by influencing water vapor transmission. In addition, previous studies [5] report consumer preferences towards larger fruits, although with unaltered organoleptic characteristics.

The effects of dehydration do not seem to be influenced by the type of fruit, as both red and white-fleshed products showed the same DR%.

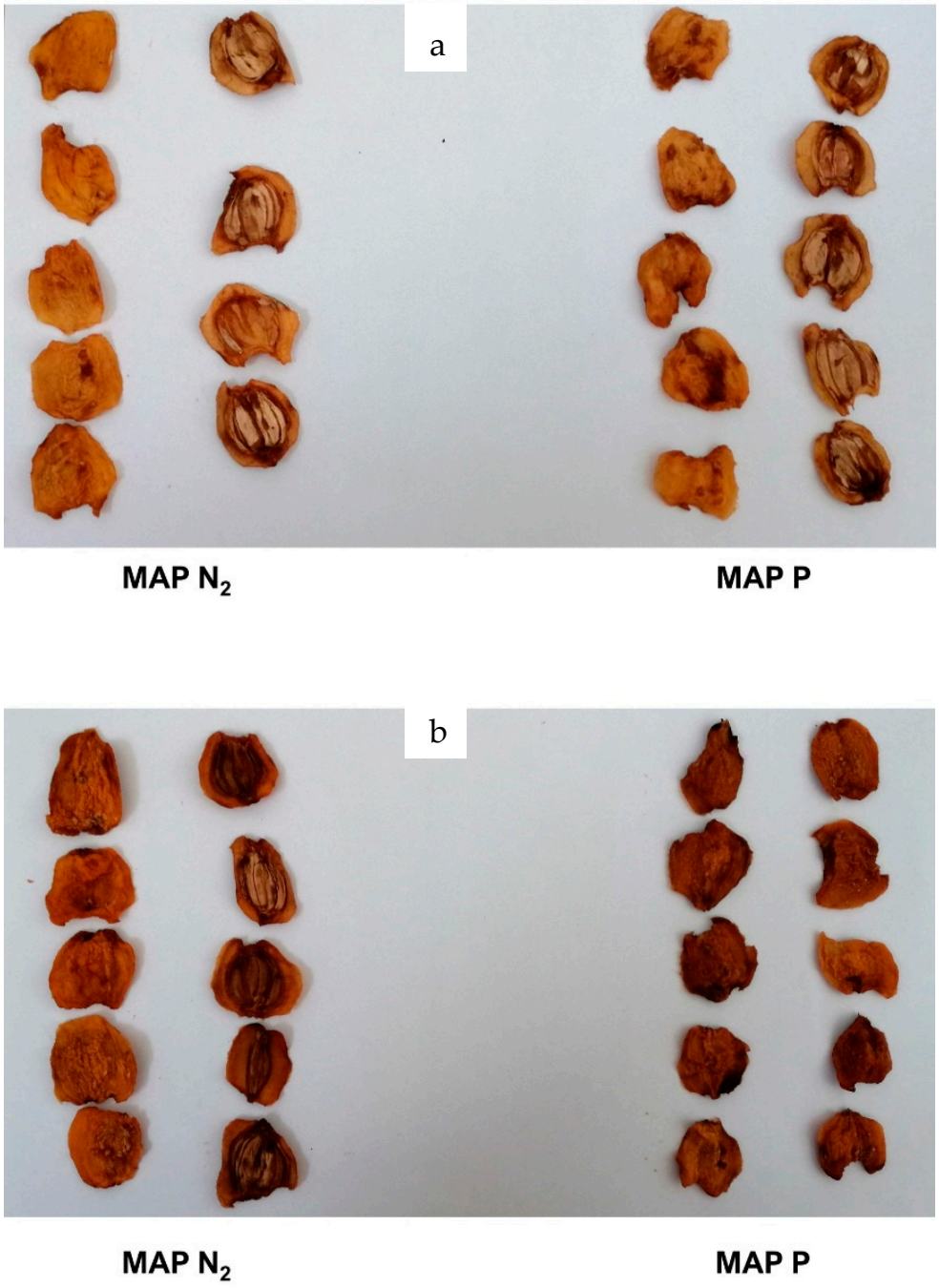

Figure 1. A representative sample of the cultivars Claudia (**a**) and Peluche (**b**) after 50 days of storage with MAP N_2 and MAP P treatment.

3.4. Firmness

The evolution of firmness of the dehydrated loquat slices over the period of storage is reported in Figure 2. Mechanical properties of the fruits are expected to change during storage [51] due to the alteration of their structural components that occurs during hot air drying [52]. Compared to the fresh fruit, white-fleshed dehydrated fruit appeared to lose more firmness at 0 days. Significant differences between passive and MAP N_2 samples were only observed in the red-fleshed fruits until 20 days of storage, while no difference emerged between the treatments after this date. Overall, red-fleshed loquat slices retained a slightly

higher firmness than the white-fleshed ones, but with no significant difference between the two groups. Throughout the storage period, we observed a slight decrease of firmness by fruits of all groups, which can be attributed to the loss of fruit turgor, compensated for by hardening due to the dehydration [53]. These results, however, are satisfactory if compared with studies conducted on several dehydrated fruits such as peach, pear, and apricot [54], which lose up to 99% of their firmness values. This is probably an effect of the controlled atmosphere storage of the fruit slices, as has been observed repeatedly by various authors [55–57].

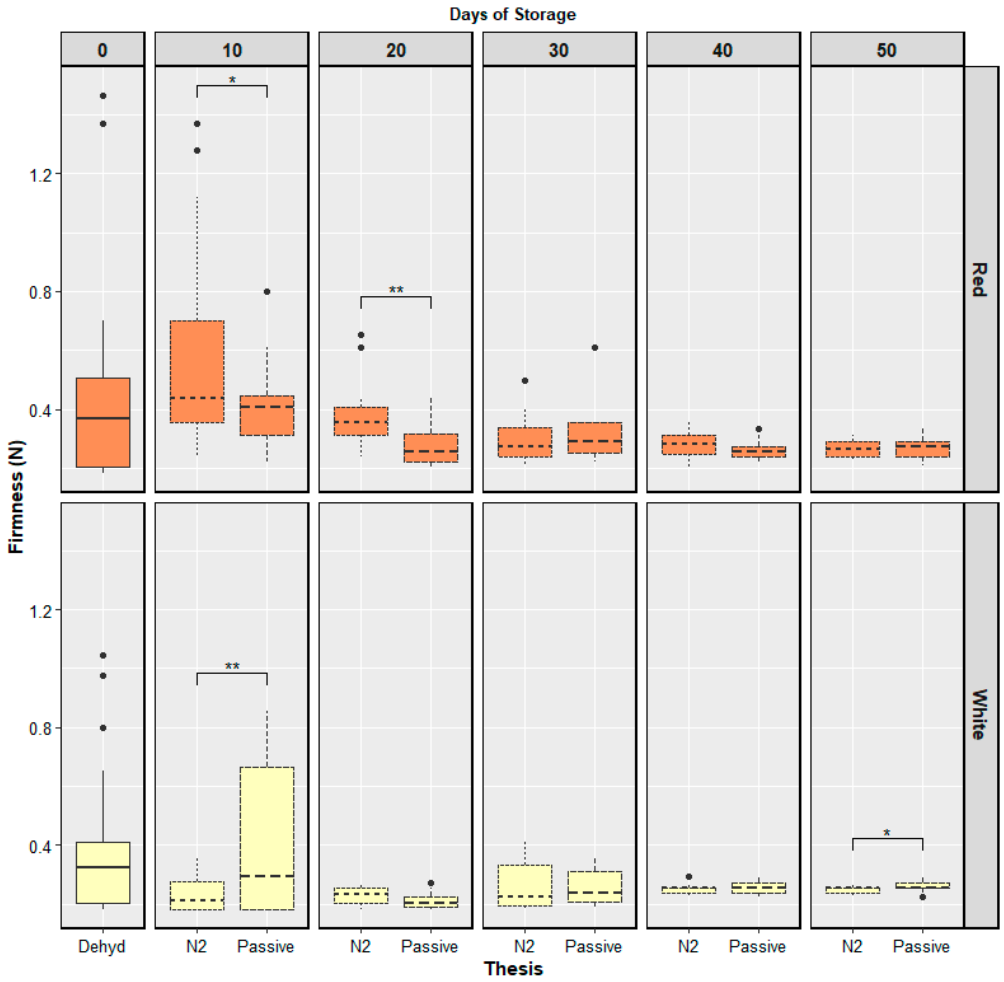

Figure 2. Firmness values of the dehydrated loquat slices over the period of storage. Asterisks between box plots indicate statistical significance of difference using Student's T-statistic with *—$p < 0.05$, **—$p < 0.01$. No asterisk indicates a non-significant difference between the means of the treatments.

3.5. Color Characteristics

Median color of the dehydrated loquat slices is reported in Figures 3–5. The dehydration process obtained a product with higher chroma than the fresh fruit, with this value increasing from 26 and 42 for red- and white-fleshed fruit, respectively (Table 1), up to median values around 55 for both cultivars (Figure 3) In both white- and red-fleshed dehydrated loquat slices, we observed a decrease of both chroma and hue angle values after 20 days of storage (Figure 4), while significant differences between the treatments were only observed in red-fleshed loquat slices at 20 days of storage, where the MAP N_2 treatment helped to retain a brighter color compared to the untreated control samples. In general, loquat flesh turns brown soon after the fruit are peeled. Browning is mostly caused by enzymatic processes involving especially polyphenolic compounds and PPO

(polyphenol oxidase) [58–60]. Controlled or modified atmosphere packaging has been observed to maintain flesh color among other quality parameters [61]; this is confirmed by the results of our observations.

The color difference ΔE is presented in Figure 5. Up to 20 days of dehydration, both white- and red-fleshed loquat dehydrated slices maintained a low value of ΔE, which reflects the fact that the color of the stored slices is similar to that of the just-dehydrated ones, while a major alteration in color of the slices was reached only after 30 days of storage. The only significant difference between the treatments was observed in red-fleshed loquat slices after 20 days of storage, where MAP P stored slices showed a higher color difference than the MAP N_2 stored ones. The results of our observations represent an improvement compared to the behavior of fresh-cut, non-dehydrated loquat fruit, which were observed to reach ΔE values of 20 after 10 days of cold storage [62]. Hence, we could conclude that the dehydration treatment allowed loquat slices, regardless of flesh color and packaging atmosphere, to maintain an attractive color until 20 days after dehydration, and significant nonenzymatic browning [63–65] started to manifest only after that moment.

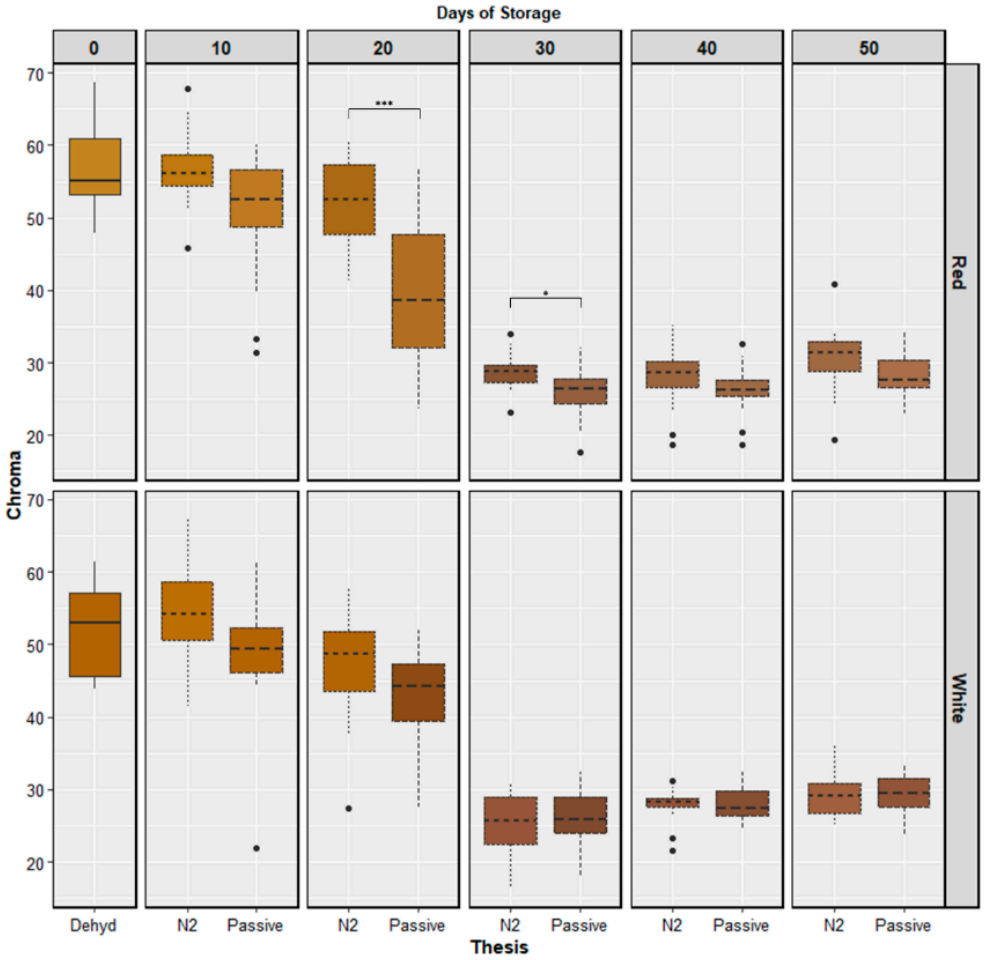

Figure 3. Chroma (C^*_{ab}) values of the dehydrated loquat samples analyzed over the course of the experiment. Box plots are filled with the median color value of the group, transformed from the CIE $L^*a^*b^*$ color space into printable hexadecimal values using the R package color-space. Asterisks between box plots indicate statistical significance of difference using Student's T-statistic, with *—$p < 0.05$, and ***—$p < 0.001$. No asterisk indicates a non-significant difference between the means of the treatments.

3.6. Microbial Analysis

The microbiological characterization performed by plate count on the fresh and dehydrated slice loquat samples involved the microorganisms responsible for the microbial

spoilage of fruits and vegetables [66], as well as the main human pathogens associated with agricultural products consumed raw [67]. The results of plate counts performed on fresh fruits of both cultivars object of study (Peluche and Claudia) showed detectable levels of the sole TMM and molds at about 10^3 CFU/g. Soon after dehydration at 50 or 70 °C for 12 h and at each sampling time (T 10; T 20; T 30; T 40; T 50), all sliced loquat samples packaged with MAP P and MAP N_2 were characterized by undetectable levels of all microbial groups investigated. The absence of microorganisms is imputable to the drying process, which reduces moisture percentage and free water necessary for the proliferation and survival of microorganisms [21], even though dry foods can be responsible for out-breaks caused by *Cronobacter* spp., *E. coli*, *L. monocytogenes*, *Salmonella* spp., and *Staphylococcus* spp. [68,69]. In particular, members of the genus *Staphylococcus* and *Salmonella* have been found in dried commercial samples of raisins and prunes [70], while *E. coli*, *L. monocytogenes* have shown the ability to survive on dried apricots [71]. To this purpose, the evaluation of microbial safety of dried fruits deserves particular attention.

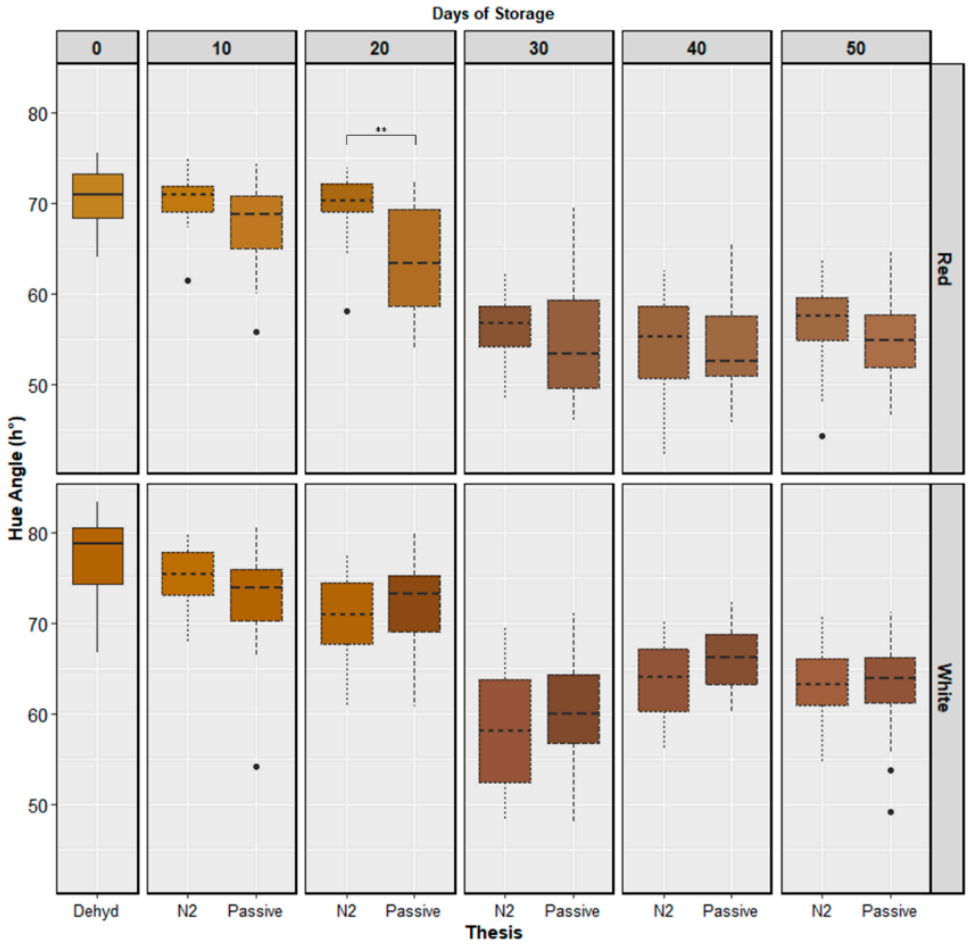

Figure 4. Hue angle ($h°$) values of the dehydrated loquat samples analyzed over the course of the experiment. Box plots are filled with the median color value of the group, transformed from the CIE *L*a*b** color space into printable hexadecimal values using the R package color-space. Asterisks between box plots indicate statistical significance of difference using Student's T-statistic, with **—$p < 0.01$. No asterisk indicates a non-significant difference between the means of the treatments.

3.7. Proximate Compounds

The results show that the vitamin A and C content decreases immediately after the dehydration process of both white- and red-fleshed loquat fruits, probably due to prolonged exposure to high temperatures. Indeed, as vitamins are thermolabile, many studies confirm that their concentration is reduced during high temperature treatment [72]. In agreement

with these studies, our work shows a greater reduction in vitamin A and C content just after the dehydration process, which lasted a total of 12 h. Furthermore, to confirm this thesis, the data show that during the 50 days of storage, the fruits continue to lose their vitamin content, but not significantly, compared to the peak shown after the dehydration process. In particular, for the red-fleshed fruit (Peluche Cv.), the initial vitamin A content was 0.89 mg/100 g of the flesh. After the dehydration process of 12 h, there was a reduction in its content of 27.33%; while, after 50 days of storage, the vitamin A content was reduced by a total of 36% (in MAP P) and 26% (in MAP N_2). As for vitamin C (ascorbic acid), it had an initial value (fresh product) of 1.36 mg/100 g of flesh, which decreased by 49.67% immediately after dehydration. In the days following dehydration, storage with MA (modified atmospheres) resulted in a decrease of 48% of its concentration in MAP P and 38% in MAP N_2, (after 50 days of storage). Furthermore, it was observed that by the tenth day of storage, the MAP P treatment had already lost 20 and 11% of its vitamin A and C content, respectively, while loquat slices stored in MAP N_2 lost only 14% (vitamin A) and 5% (vitamin C) of their content compared to the initial post-dehydration data. For the white-fleshed loquat fruit (Claudia Cv.), however, the initial value of the vitamin content was 0.70 mg (vitamin A) and 1.17 mg (vitamin C) per 100 g of the flesh. After the dehydration process, they lost about 35% and 5% of their initial content, respectively. After packaging and analysis for 50 days of storage, it was found that MAP P packaging resulted in a loss of vitamin A and C content of 45 and 55% respectively, whereas MAP N_2 packaging reduced the content of these vitamins by 30 and 38% compared to the initial value post dehydration. However, as found in other studies [73], loquat fruits have been shown to be a poor source of vitamin C considering, for example, that fruits such as oranges or apples contain about 40 mg and 8 mg of ascorbic acid, respectively, in 100 g of fresh produce, although this varies according to the cultivars analyzed [46]. Considering that consumers prefer commercial products not only because of their larger size, but also because they do not lose their organoleptic and nutraceutical characteristics [74], loquat fruits treated with the dehydration process and then packaged with MAP P and MAP N_2 showed numerous differences. In fact, it is worth mentioning that packaging with N_2 resulted in the retention of the analyzed vitamins until the end of the monitoring period (50 days). Regarding the analysis of minerals, the content of K, Na, Ca, Mg, and P in 100 g of flesh was analyzed both at the time of cutting (as a fresh product at d0), after dehydration (12 h), and during the following 50 days of storage with the different MA. From Table 4, it is possible to notice how the dehydration treatment determined a different performance according to the minerals analyzed. In particular, the K and P content decreased from d0 to d50, while the concentration of the other minerals (Na, Ca, and Mg) increased. According to some studies [75] the lower the water content, the higher the concentration of minerals. In addition, some significant differences were found, as shown in the table, which indicate different behaviors of the packaging methods, particularly during the last days of storage. The statistics show that there is a clear maintenance of the mineral content in the treated loquat slices packed with MAP N_2. There seems to be a difference of about 20% in the mineral content on the last day of storage between MAP P and MAP N_2. On the differences between the two cultivars (Peluche and Claudia), it is not reasonable to compare these data because the initial concentrations at the time of cutting were different, so it was not possible to determine any differences in mineral content between the red-fleshed and the white-fleshed cultivars. Although the identification of this data is crucial, it was not possible to compare it with other literature data, as there are no studies carried out on the analysis of minerals and proximate compounds in general for dehydrated loquat fruits. In addition, Ca, K, and P, together with a low Na intake, are associated with protection against bone demineralization, arterial hypertension, insulin resistance, and overall cardiovascular risk. Therefore, it was essential to highlight the content of these compounds in loquat fruits and to analyze any differences in order to identify the most appropriate preservation method for better retention of these compounds in the flesh.

3.8. Sensory Analysis

A sensory analysis was conducted by a panel over the period of storage of the dehydrated loquat slices. Results of the panel evaluations are presented in Figure 6. The descriptors which, over the time of the experiment, always obtained the highest scores were odor of honey (OH), flavor of caramel (FC), and sweet (SW). The negative descriptors off odor (OO), acid (A), and sour (S), on the other hand, were the ones which obtained the lowest scores throughout the storage period, No significant differences emerged between the MAP N_2 samples and the MAP P at any given observation moment, but it is possible to notice a decrease in the scores obtained in some of the descriptors over time: in particular, the descriptors juiciness (JUI) and flavor of loquat (FL) are the ones that showed the biggest decrease in scores in the evaluation by the panel members.

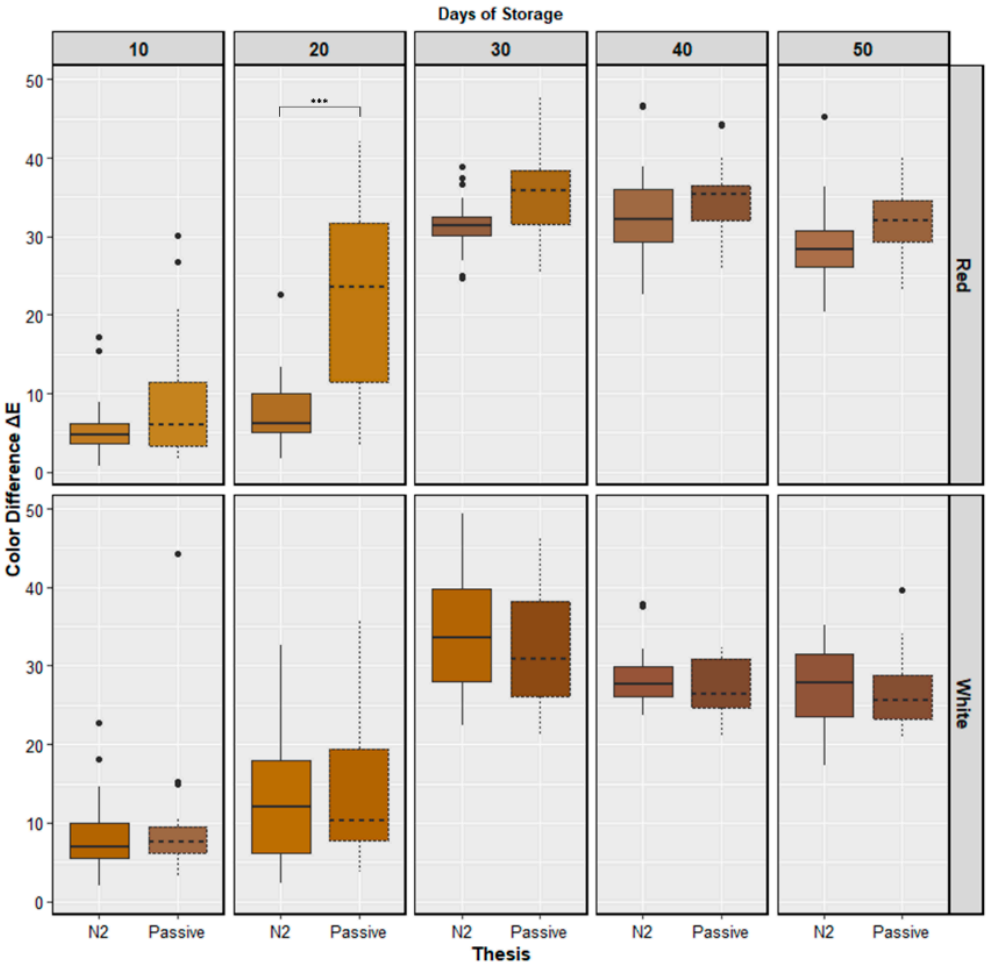

Figure 5. Color difference (ΔE) of the dehydrated loquat slices compared after the various storage times compared to the color measured on the freshly dehydrated slices just after the dehydration process. Box plots are filled with the median color value of the group, transformed from the CIE *L*a*b** color space into printable hexadecimal values using the R package color-space. Asterisks between box plots indicate statistical significance of difference using Student's T-statistic, with ***—$p < 0.001$. No asterisk indicates a non-significant difference between the means of the treatments.

Table 4. Content of K, Na, Ca, Mg, and P per 100 g of fresh product, dehydrated (T_0) and after 10, 20, 30, 40, and 50 days of storage with MAP P and MAP N_2. The table shows means ± SD (n = 3); lower case letters show statistically significant differences ($p \leq 0.05$) and the * indicates statistically significant differences between minerals in fruit packed with different MAP.

Peluche Cv.—Mineral Composition (mg/100 g)					
	MAP P				
	K	**Na**	**Ca**	**Mg**	**P**
Fresh	228.66 ± 2.79 a	10.66 ± 1.51 b	15.00 ± 1.00 c	11.66 ± 1.08 d	23.00 ± 1.36 a
T_0	205.00 ± 2.50 b	12.00 ± 1.00 ab	15.66 ± 1.15 c	12.00 ± 2.00 c	11.66 ± 1.00 b
T_{10}	201.00 ± 2.06 b *	13.66 ± 2.00 a	20.67 ± 1.00 bc	13.66 ± 1.06 bc	11.66 ± 1.06 b
T_{20}	196.66 ± 2.00 b	13.75 ± 2.00 a	20.70 ± 1.31 b	14.66 ± 1.06 b	11.33 ± 1.15 b
T_{30}	190.00 ± 2.00 c	14.00 ± 2.00 a	21.25 ± 2.00 b	14.66 ± 1.00 b	10.66 ± 1.53 bc
T_{40}	162.27 ± 2.00 d *	14.00 ± 2.31 a	21.50 ± 1.00 ab	16.66 ± 1.00 a	10.66 ± 1.53 bc
T_{50}	143.33 ± 2.90 e *	14.00 ± 2.00 a	22.00 ± 1.00 a	16.66 ± 1.08 a	9.66 ± 1.50 c
	MAP N_2				
	K	**Na**	**Ca**	**Mg**	**P**
Fresh	228.66 ± 2.79 a	10.66 ± 1.51 e	15.00 ± 1.00 e	11.66 ± 2.08 d	23.00 ± 4.36 a
T_0	205.00 ± 2.50 b	12.00 ± 1.00 d	15.66 ± 1.15 de	12.00 ± 2.00 c	11.66 ± 1.00 b
T_{10}	196.67 ± 2.88 bc *	13.66 ± 1.30 cd	16.00 ± 3.05 d	13.66 ± 1.57 b	11.67 ± 3.04 b
T_{20}	195.00 ± 2.00 c	14.00 ± 2.00 c	16.00 ± 2.00 d	13.66 ± 1.52 b	11.00 ± 1.00 c
T_{30}	191.33 ± 2.30 cd	14.00 ± 2.00 c	18.00 ± 2.08 c	14.67 ± 3.05 ab	10.66 ± 1.52 c
T_{40}	190.00 ± 2.00 d *	15.00 ± 1.08 b	20.00 ± 1.00 b	14.66 ± 2.08 ab	10.66 ± 1.27 c
T_{50}	173.33 ± 2.00 e *	17.00 ± 2.01 a	22.00 ± 3.60 a	15.00 ± 1.52 a	9.00 ± 1.53 d
Claudia Cv.—Mineral Composition (mg/100 g)					
	MAP P				
	K	**Na**	**Ca**	**Mg**	**P**
Fresh	128.66 ± 2.79 a	24.00 ± 2.64 e	15.00 ± 1.00 d	11.66 ± 2.08 e	11.00 ± 1.00 a
T_0	110.00 ± 2.00 b	28.00 ± 2.00 de	15.00 ± 1.00 d	11.00 ± 1.03 e	11.66 ± 1.51 ab
T_{10}	105.00 ± 2.00 c	29.00 ± 2.00 d	15.66 ± 1.15 d *	13.66 ± 0.57 d	11.66 ± 1.52 ab
T_{20}	103.33 ± 2.72 d	31.00 ± 1.60 c	17.00 ± 2.00 c *	14.00 ± 0.11 cd	11.66 ± 1.52 ab
T_{30}	101.33 ± 2.00 e	33.66 ± 2.30 bc	22.00 ± 2.00 b	14.66 ± 1.05 c	11.66 ± 1.52 ab
T_{40}	101.00 ± 2.93 e	34.00 ± 1.63 b *	25.00 ± 1.00 a	21.00 ± 1.08 b *	9.00 ± 1.00 b
T_{50}	100.00 ± 1.90 f	41.00 ± 1.00 a	25.00 ± 1.00 a	23.00 ± 0.57 a *	9.66 ± 1.53 b
	MAP N_2				
	K	**Na**	**Ca**	**Mg**	**P**
Fresh	128.66 ± 2.79 a	24.00 ± 2.64 e	15.00 ± 1.00 d	11.66 ± 1.08 de	11.00 ± 1.00 a
T_0	110.00 ± 1.62 b	28.00 ± 2.00 d	15.00 ± 1.00 d	11.00 ± 1.03 e	11.66 ± 1.51 ab
T_{10}	106.00 ± 2.00 c	29.00 ± 2.00 cd	22.00 ± 2.00 c *	11.66 ± 1.5 de	11.33 ± 1.52 b
T_{20}	105.00 ± 2.00 cd	31.00 ± 1.00 c	22.66 ± 1.30 bc *	12.00 ± 1.05 d	10.66 ± 1.15 c
T_{30}	103.33 ± 2.72 d	31.00 ± 1.00 c	23.00 ± 2.00 b	13.66 ± 0.50 c	10.66 ± 1.52 c
T_{40}	103.33 ± 2.58 d	41.00 ± 1.00 b *	25.00 ± 1.00 a	14.66 ± 0.57 b *	9.66 ± 1.53 d
T_{50}	101.33 ± 2.93 e	44.00 ± 2.45 a	25.00 ± 1.00 a	16.66 ± 1.27 a *	9.00 ± 1.06 d

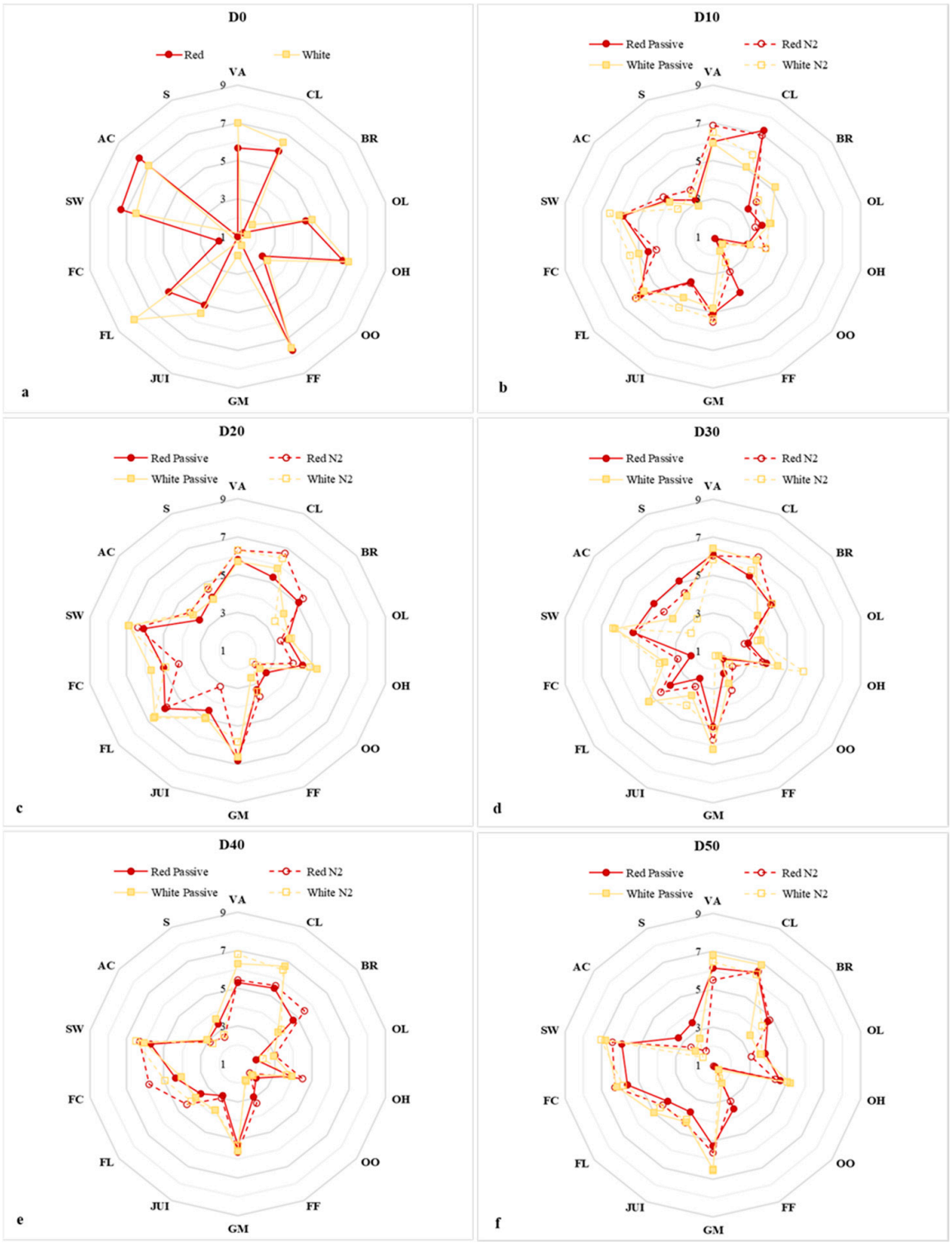

Figure 6. Results of the sensory analysis conducted on the dehydrated loquat slices at 0 (**a**), 10 (**b**), 20 (**c**), 30 (**d**), 40 (**e**), and 50 (**f**) days of storage. Legend: visual appearance (VA); color (CL); browning (BR); loquat odor (OL); honey odor (OH); off-odor (OO); crispness (FF); softness (GM); juiciness (JUI); loquat flavor (FL); caramel flavor (FC); sweetness (SW); acidity (AC); sourness (SO).

4. Conclusions

Our results highlights that the tray drying treatment at 70° for 12 h had a good drying efficiency to obtain high quality loquat slices for both white- and red-fleshed loquat fruit.

The dehydration process, as can be clearly seen in the reduction in the size of the slices (LD and TD), ensured that the water contained in the fresh fruit was properly removed, resulting in a product with a high shelf life, as evidenced by the number of days it was been stored. Firmness of the loquat slices changed slightly during storage due to the alteration of their structural components, which occurs during hot air drying. However, firmness was pleasant to the mouth, as confirmed by the sensory analysis results, which showed a positive rating for most descriptors, including the defect ratings. Slices maintained an attractive color after dehydration, and MAP treatments limited significant nonenzymatic browning for a long period of storage. From the microbiological point of view, both dehydration and MAP treatments maintained food safety, since all sliced loquat samples were characterized by undetectable levels of all microbial groups investigated after up to 50 days of storage.

From an applicative perspective, convective tray drying makes it possible to use loquat fruit that would have been excluded from the market and to position them usefully as processed products by enhancing the value of supply chain waste. The approach is useful on a small scale, but could be also easily industrialized.

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