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Research article

Tray-drying is a new way to valorise white-fleshed peach fruit

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Abstract: Pescabivona is a highly appreciated fruit by consumers for its sweet flavour and juicy flesh; however, it has a short shelf life and is susceptible to postharvest damage, such as mechanical injury, loss of texture and alteration of organoleptic properties. Therefore, it's necessary to develop new methods of processing and conservation for this fruit. The aim of this study was to analyse the effects of tray-drying in white peach slices and cubes at 70 °C for 12 hours in order to extend their shelf-life and increase its commercial availability over a long period and to obtain a new food product. The physicochemical and sensory properties of dried fruits were assessed during 30 days of storage in polyamide/polyethene (PA/PE) bags containing two gas mixtures (treatments): MAP-N_2 (100% N_2) and MAP-P (78% N_2, 21% O_2 and 0.04% CO_2), at room temperature (20 ± 1 °C). Both MAP treatments kept the fruit firmness, with MAP-P slightly more effective. Slicing produced fruit with a good appearance and firmness, while cubing produced sweet fruit with a caramel flavour and a chewier firmness. In addition, packing with MAP-N_2 reduced the phenomenon of fruit browning. Overall, this study provides significant information on the drying process (time-temperature treatments) and packaging techniques (MAP) of white-fleshed peach to obtain a novel food product.

Keywords: pescabivona; post-harvest; fruit quality; dried fruit; modified atmosphere packaging; sensory analysis

Abbreviations: MAP: modified atmosphere packaging; S: slices; C: cubes; MAP-N_2: active MAP; MAP-P: passive MAP; LD: longitudinal diameter; TD: transverse diameter; C*: chroma; ΔE: colour differences; BI: browning index; %DR: dry residue; FF: firmness; TSSC: total soluble solids contents; TA: titratable acidity.

1. Introduction

The peach (*Prunus persica* (L.) Batsch) is the second most cultivated fruit in the world. Within the European Union (EU), Italy is the leader in peach production. In northern Italy, mainly in Emilia-Romagna, nectarines represent 50% of new orchards, while in southern Italy peaches are preferred. At the end of the 1970's the peach industry in Sicily was still based on clingstone white fleshed local types, called "montagnole" (fruits of the mountains), nectarine-type, white-fleshed, named "Sbergie" and flat-type named "Tabacchiere" [1]. In the '90s, peach and nectarine cultivars were introduced from the USA, consequently, a renewal of Sicilian orchards started [2]. In any case, white-fleshed peaches remain an important part of Sicilian production. In particular, Pescabivona, also known as "Pesca di Bivona," is an indigenous cultivar grown only in its original area, the Bivona area, located in the Middle-West Sicily [3]. Pescabivona includes four native varieties: *Murtiddara* (also known as *Primizia Bianca*), *Bianca*, *Agostina* and *Settembrina.* These varieties ripen at different times, from late June (Murtiddara) to late September (Settembrina) [4]. The Pescabivona cultivation area falls within the Sicani Mountains and includes the territories of Bivona, Alessandria della Rocca, Santo Stefano Quisquina and San Biagio Platani, in the province of Agrigento and Palazzo Adriano, in the province of Palermo [5]. Pescabivona obtained protected geographical indication (PGI) certification in 2014, and the product specification indicates peach fruits with a white non-melting flesh, characterized by a spheroidal shape and a creamy-yellow background skin colour with an extent of red over coloration (50%) for Murtiddara, followed by Agostina and Settembrina (40%) [6]. In addition, Settembrina has a peculiar red stripe along the suture line, due to a mutation involving the epidermal layer [7]. Its flavour is sweet and aromatic. Its odour stands out from the peaches produced in the rest of Sicily and Italy, due to its inebriating and persistent nature [5]. Furthermore, Pescabivona is highly valued for its organoleptic properties and high firmness. In fact, the fruit has been classified as non-melt, with sugar and phenolic content, finding considerable interest from the local market and large-scale organized distribution [8]. On the other hand, white fleshed peaches soften rapidly after commercial ripening, are very susceptible to chilling injuries and can be easily damaged during storage [9].

Peach is a climacteric fruit and, after harvest, numerous physiological and metabolic processes (respiration, transpiration, flesh softening, etc.) continue in it, drastically increasing ethylene production at a rate closely related to the storage temperature [10]. Being a white-fleshed peach, the main critical problems found on Pescabivona are related to strong seasonality, reduced fruit shelf-life, enzymatic browning, susceptibility to cold and handling damage [5,11]. Ripening time influences dramatically fruit quality and, for this reason, it is important to individuate the optimal period [12]. Recently, several postharvest treatments have been studied to reduce and limit cold damage, including the application of salicylic acid, jasmonic acid, 1-methylcyclopropene, controlled atmosphere, ozone and radiation [13–15]. In addition, techniques such as refrigeration are nonresolving and limit shelf-life due to the possible development of pathogens and damage caused by low temperatures, as well as the considerable environmental impact they cause, in some cases reducing consumer's purchasing intention [16–19]. Today, consumers also prefer to buy fruit close to physiological ripeness, when there is maximum expression of the sensory and organoleptic profile [20]. This creates technical problems related to reduced shelf-life due to senescence, increased waste due to microbial spoilage and altered visual appearance of fruit.

Post-harvest waste of fruit and vegetables is alarming and represents a major challenge in the food supply chain due to its negative social, economic and environmental impact [21]. It is estimated that 20–60% of total production and many fruit and vegetables are lost and wasted along the food chain [22,23]. Among the possible techniques to prevent post-harvest losses of white-fleshed peaches, also given their seasonality and short shelf life, is tray-drying [24]. In addition, recent studies have reported a significant increase in the consumption of dried fruit, due to the many benefits of regular consumption of these products [25–27]. In recent years, there has been an increasing demand for these products in their many formats (mixes, bars, single portions, etc.), which are well suited to the different needs of consumers [28].

Drying is an old method based on the partial or total reduction of water content in the form of steam to a final concentration (10–14% RH) that ensures microbial stability and improves shelf life [29]. The drying treatment also leads to the breakdown of cell structures and the loss of membrane semi-permeability, resulting in a change in rheological properties. In fact, the outer layers of the dried matrix become rigid and protein aggregation takes place [30]. However, structural changes depend on the drying method and the residual moisture in the plant tissue. Drying processes influence the colour, flavour, texture and functional properties of fruit [24,31]. The oldest drying method is exposure to the sun, which allows a product with good quality characteristics but prone to environmental contamination [32], as well as being an extremely slow process. Using machines, however, heat invests the whole fruit or pieces/slices by conduction, convection and radiation [33,34]. Hot-air drying is an alternative method that yields a qualitatively superior product using low temperatures and short processing times [35].

The basis of the drying process, along with the healthy element, the taste experience and the convenience of consumption, environmentally friendly preservation systems must be implemented that promote food shelf life and safety. Dried products must also be stored properly to maintain their quality and nutritional characteristics for a prolonged period.

Among the different storage systems, MAP, maintains the qualitative characteristics of perishable products for a prolonged shelf life [36–38]. The principle behind MAP is to replace the atmosphere surrounding a product before sealing by mixing carbon dioxide, oxygen and nitrogen (the most commonly used gases) at different concentrations. The modified atmosphere is useful because it reduces the oxidation of food products and, consequently, the production of compounds that cause the loss of colour, aroma and taste [39]. The use of inert gases, such as nitrogen, not only prevents package collapse but also helps prevent microbial growth, which is another factor contributing to product degradation [40]. Several studies [24,41] have shown that MAP treatments with 100% N_2 limit significant nonenzymatic browning, while maintaining weight and firmness characteristics over a long storage period.

This work aims to investigate the effects of hot-air drying technique and MAP during 30 days of storage on the quality of slices and cubes of white-fleshed peaches. In this way, it is intended to enhance a fruit that is highly susceptible to post-harvest damage, prolonging its shelf life and allowing a wider commercial distribution. At the same time, it is also aimed at using fruit that does not conform to commercial standards to reduce waste.

2. Materials and methods

2.1. Plant material

Peach fruits (*Prunus persica* Batsch) cv. Pescabivona var. Settembrina, ready to consumption with typical taste (sweetness ≥ 10 °Brix), colour (overcolour ≤ 50%) and texture (≥34.3 N)were used [42]. The fruits were harvested at the "Soletta" Farm, located in the city of Castronovo di Sicilia (PA) (37°40'27.98"N; 13°39'12.55"E, 371m a.s.l.). After harvest, the fruits were stored at 5 ± 1°C and after 24 h were subjected to analysis. Pomological characterization of was carried out on a sample of 20 fresh fruits.

2.2. Experimental design

Due to the lack of literature data, several preliminary tests on drying peach fruit were conducted to find the right time/temperature combination and whether to dry the fruit with or without the peel. For this reason, the initial preliminary test involved unpeeled fruit, dried for 12 h at 70 °C. However, although the time/temperature combination proved to be effective in terms of maintaining organoleptic and sensory characteristics, it was found that the presence of the epicarp, after drying, causes excessive wrinkling, resulting in an uneven and aesthetically unappealing product (data not shown). Hence, the definitive experimental protocol involved the use of fruit peeled and dried for 12 h at 70°C.

The whole fruits were washed and sanitized with distilled water (20 ± 5 °C) and 200 µL-L NaClO (5–6.5% NaClO solution, CHEMLAB) for 10 min. Then, the fruits were peeled, de-stoned and cut with a curved knife to a thickness of 5 ± 0.5 mm as follows:

- Slices (S)
- Cubes (C)

To prevent browning, the fruit were dipped in natural anti-browning agents [43], for 2 min. The antioxidant solution was obtained by dissolving citric acid (99.5–101% $C_6H_8O_7.1H_2O$, CHEMLAB) and ascorbic acid (99+% $C_6H_8O_6$, CHEMLAB) in distilled water at concentrations of 0.5 g/0.5 L. drying process was conducted by means of a convective hot-air dryer operating at constant temperature. The dryer consists of a stainless-steel chamber (86 cm x 86 cm x 76 cm) provided with an electric heater to heat the air and a centrifugal fan to feed the airflow and recirculate it. The samples were put on the grids of mesh of size 0.01 m x 0.01 m in the dryer and, after that, they are dried at 70°C for 12 h at a centrifugal fixed air velocity of 2.3 m/s until the relative humidity was constant(14–16%R.H.), according to Diaz [44] and Kesbi [45]. Dried fruits were stored in MAP and specifically, two treatments were applied to understand the effect of modified atmosphere packaging:

- MAP-N_2 (100% N_2);
- MAP-P (78% N_2, 21% O_2 and 0.04% CO_2).

The samples were packed in polyamide/polyethylene bags composed of 80% polyamide and 20% polyethylene, with a thickness of 90 µm and a volume of 500 cm^3, 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) [46]. A 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).

Each bag contained 100 g of dried fruit divided according to the type of cut and treatment:

- MAP-packed cubes (MAP-N_2 C)

- MAP-packed slices (MAP-N_2 S)
- MAP-P packed cubes (MAP-P C)
- MAP-P packed slices (MAP-P S)

Samples were stored at room temperature (20 ± 1℃) for 30 days and analyses were performed every 10 days (D10; D20; D30).

2.3. Physico-chemical analysis

Fresh weight (FW-g) was measured with a precision electronic scale (Gibertini EU-C 2002 RS, Novate Milanese, Italy), while fruit longitudinal diameter (LD-mm) and fruit transverse diameter (TD-mm) were measured with a digital calliper (Turoni TR53307, Forli, Italy). The colour of the fruit was determined based on the CIE L*a*b* colour system [brightness (L*); red/green (a*); yellow/blue (b*)] by means of digital colorimeter (CR-400 Chroma Meter, Minolta, Japan). Colorimeter calibration was performed against a white plate (illuminants C: Y ¼ 89.53, x ¼ 0.3247, y ¼ 0.3198) before each measurement. For each sample, the parameters L*, a* and b* were measured and the averages of all measurements were determined for each package. Chroma (*C**) values, which indicate the quantitative attribute of colour intensity, have been calculated using Equations (1), to characterize fresh sample: [47]:

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

Total colour difference (ΔE), between the colour of fresh fruit and that of the fruit after drying for both types of cut were measured at D0, following the Equation (2) [47]:

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

where L^*_0, a^*_0 and b^*_0 represent lightness (L*), redness (a*) and yellowness (b*) of the samples after drying, respectively. In addition, the browning index (BI) at each observation during the 30 days of storage was measured with the following Equation (3) [48]:

$$BI = \frac{(x - 0.31)}{0.17} \times 100 \quad (3)$$

where $x = (a* + 1.75\,L*)/(5.645\,L* + a* - 0.3012\,b*)$.

The firmness (FF) of the slices and cubes was measured using a durometer (Durofel Agrosta 100 Field, Serqueux, France) and converted to Newtons using Equation (4) [49]:

$$N = 9{,}8\left(e^{\frac{Durofel - 59.32}{14.89}}\right) \quad (4)$$

Total soluble solids content (TSSC) was measured by means of digital refractometer (Atago, Tokyo, Japan) and the values were expressed as °Brix; while titratable acidity (TA g/L^{-1} malic acid) was measured with a pH meter-titrator (Titromatic 1S, Crison, Barcelona, Spain) and expressed as grams of malic acid per litre of fruit juice (g L^{-1} malic acid) using 5 mL of juice diluted in 45 mL of distilled water. The dried fruit was checked for drying efficiency (DR%), which was calculated using Equation (5) [50] :

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

where:
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

2.4. Sensory evaluation

Sensory evaluation was carried out by a team of 30 judges with good training and knowledge in this type of food evaluation [51], following the guidelines of UNI 10957:2003 [52]. During the preliminary test, 15 qualitative descriptors were chosen for sensory profiling, generated on the basis of citation frequency (>60%) and listed below: *visual appearance* (VA); *firmness* (FR); *peach odour* (PO); *honey odour* (HO); *off-odour* (OO); *acidity* (AC); *sweetness* (SW); *bitterness* (BT); *juiciness* (J); *crispness* (CR); *rubberness* (RU); *peach flavour* (PF); *caramel flavour* (CF); *off-flavour* (OF); *degree of browning* (B). The evaluation was conducted from 10 to 12.00 in a room with white lights. Each judge received, in random order, a sample of three pieces of fruit, by cut and treatment. Between each sample, water was provided to rinse the mouth. The judges rated the intensity of each descriptor on a hedonic scale by assigning a score between 1 and 9, where: 1 - no sensation, 2 - scarcely discernible, 3 - very low, 4 - low, 5 - slight, 6 - moderate, 7 - intense, 8 - very intense and 9 - extremely intense [53].

2.5. Statistical analysis

Using the XLSTAT software (Addinsoft, Paris, France), repeated measures ANOVAs and Tukey's honestly significant difference (HSD) tests ($p \leq 0.05$) were performed for all parameters studied to assess significant differences between the treatments and days of storage.

3. Results and discussion

3.1. Fresh fruit

A preliminary physicochemical characterization was carried out on a sample of 20 fresh fruit before drying (Table 1).

Table 1. Qualitative characteristics of fresh Pescabivona var. Settembrina fruit. TSSC values (total soluble solids content, Brix); TA (titratable acidity, g/L^{-1} malic acid); FF (firmness; N); TSSC/TA ratio. Values are represented as mean ± SD.

	TSSC (°Brix)	TA (g malic a./L)	FF (N)	C* (Chroma)	TSSC/TA
Pescabivona var. Settembrina	12.93 ± 0.40	0.18 ± 0.07	0.20 ± 0.01	27.60 ± 0.53	71.83

From the obtained data, it can be said that peach fruits are sweet and low in acidity, with an intense coloration tending toward yellow/orange, according to Montevecchi et al. [54]. Crisosto et al. [55] demonstrated a higher acceptance of grapes with a high TSSC/TA (greater than 25.0) among U.S. consumers. From the obtained data, the TSSC/TA ratio reached 73.83 confirming a degree of ripeness close to consumption and therefore closer to consumer preferences. These data have been considered important to determine the initial characteristics of the fruit and the differences between fresh and dried products.

3.2. Longitudinal and transverse diameter and dry residue

During the drying process, longitudinal (LD) and transverse (TD) diameter values decreased in both types of cuts (slices and cubes). The porous and hygroscopic nature of fruits and vegetables makes them highly shrinkable during drying [56].

Table 2. Temporal trend of longitudinal (LD) and transverse (TD) (mm) diameters of slices (a) and cubes (b) of Pescabivona var. Settembrina. Diameter data are expressed as mean values ± SD. Values in the same column followed by a different letter are significantly different ($p < 0.05$); ns = non-significant; asterisks indicate statistically significant differences between MAP treatments at the same storage day with * $p < 0.05$; no asterisks indicate the non-significant difference between treatment means.

(a)	Slice (S)	
	LD	TD
Fresh	57.57 ± 1.71	25.20 ± 1.81
Post drying	49.80 ± 5.47^{ns}	19.28 ± 3.23^{ab}
D10 MAP-P	48.46 ± 4.61	20.92 ± 1.40^{a}
D20 MAP-P	49.60 ± 6.02	19.75 ± 2.43^{a}
D30 MAP-P	46.00 ± 2.49*	17.30 ± 2.94^{b}
Post drying	49.80 ± 5.47^{ab}	19.28 ± 3.23^{a}
D10 MAP-N_2	50.87 ± 5.89^{a}	19.75 ± 2.01^{a}
D20 MAP-N_2	45.45 ± 7.49^{bc}	18.60 ± 2.35^{a}
D30 MAP-N_2	41.80 ± 4.84^{c,}*	16.15 ± 3.86^{b}
(b)	Cubes (C)	
	LD	TD
Fresh	36.07 ± 1.36	24.56 ± 1.13
Post drying	27.31 ± 1.83^{a}	18.53 ± 1.43^{ab}
D10 MAP-P	25.33 ± 4.06^{ab}	19.95 ± 3.74^{a}
D20 MAP-P	23.60 ± 2.60^{b}	16.90 ± 1.97^{bc}
D30 MAP-P	22.65 ± 6.29^{bc}	15.45 ± 3.09^{c}
Post drying	27.31 ± 1.83^{a}	18.53 ± 1.43^{a}
D10 MAP-N_2	24.81 ± 4.81^{ab}	19.59 ± 3.29^{a}
D20 MAP-N_2	21.75 ± 4.95^{b}	15.20 ± 2.38^{b}
D30 MAP-N_2	23.40 ± 4.62^{bc}	15.15 ± 1.73^{b}

As shown in Table 2, before drying, the peach slices had a length dimension (LD) of 57.57 mm and a width dimension (TD) of 25.20 mm. After drying, these values decreased to 49.80 mm and

19.28 mm, respectively, representing a significant reduction in LD of 13.49% ($p < 0.01$) and TD of 23.49% ($p < 0.001$). Similarly, in cubes the values also decreased, with a reduction of 24.29 % ($p < 0.001$) in LD and 24.55 % ($p < 0.001$) in TD. Although no significant variation was observed for TD between the two cuts, LD was reduced (10.8% more) in the cubes. This was due to the shape and physical structure of the samples. The slices probably retained their LD due to the even distribution of heat stress they were subjected to. By comparing these data with %DR, a loss of water content of 84.57% and 83.64% was observed for S and C, respectively. For the same thickness, a higher dry efficiency was observed for slices than for cubes, probably due to the greater surface area exposed during drying.

During the 30-day storage period, the LD and TD diameters further decreased. Storage of the samples in MAP showed a significant decrease in LD in both cuts and only for MAP-P S was not significant ($p > 0.05$). In addition, a significant difference was observed between MAP-P and MAP-N_2 treatments at the end of the storage period (D30). Specifically, in the slice, the LD decreased by 3.80 mm in samples stored in MAP-P and by 8 mm in those stored in MAP-N_2, showing that, for the type of cut, storage in MAP-P is more suitable ($p = 0.01$). In the cubes, no significant changes were observed between the two MAPs treatments to D30. In fact, the LD decreased by 4.66 mm in samples stored in MAP-P and 3.91 mm in those stored in MAP-N_2.

Similarly, changes were observed for TD during the 30-day storage period. In the slices, a significant decrease of 1.98 mm was observed in the samples stored in MAP-P and 3.13 mm in the samples stored in MAP-N_2. Whereas, in the cubes, the reduction was 3.08 mm in MAP-P and 3.38 mm in MAP-N_2. There was no significant effect of MAP treatment on transverse diameter reduction in any of the cuts throughout the storage period ($p > 0.05$).

For slices, treatment with MAP-P seems to have been more appropriate, as it caused a smaller reduction in LD than treatment with MAP-N_2. In cubes, on the other hand, both MAP-P and MAP-N_2 appear to be equally effective because no significant changes were found in the reduction of transverse diameter.

The results indicate that the drying process influences LD and TD reduction while storage in modified atmosphere had no significant influence.

3.3. Firmness

One of the main changes affecting the structure of plant tissues during drying is the change in firmness [57]. The removal of water content from the fruit during the drying process results in a loss of the volume and weight, as well as a change in mechanical properties, such as hardness and crispness [58]. Fruit firmness is one of the most important quality properties, as it influences the acceptability of the fruit to consumers [59]. Manrique et al. and Mafra et al. [60,61] report that changes in fruit texture are largely determined by changes in the structure of the fruit cell wall and polysaccharides in the middle lamella.

After the drying process, there was the same significant increase of 0.1 N firmness ($p < 0.001$) in both cuts (0.30 N) compared to the fresh fruit (0.20 N). This could be due to drying, through the removal of water from the fruit tissues, increasing the concentration of solutes within the cells, causing them to become more compact and less susceptible to deformation [62]. However, it is important to consider that firmness values may also depend on other factors, such as the type of fruit, degree of ripeness, temperature and drying time used during the process [63]. Considering ripe peach for consumption, the increase of 0.1 N can be perceived as a positive result for handling and transport because it indicates a greater resistance to pressure and a greater ability of the fruit to maintain its shape and integrity [64]. However, it is also important to consider consumer preferences to determine if this result is also desirable for the market. For example, a study by Wong et al [65] showed that Korean consumers prefer apple-based dried fruit produced in South Korea with a crunchy firmness, while they prefer pear-based dried fruit produced in the United States with a soft, chewy firmness. Therefore, dried fruit companies should take these preferences into account when developing new products for different markets.

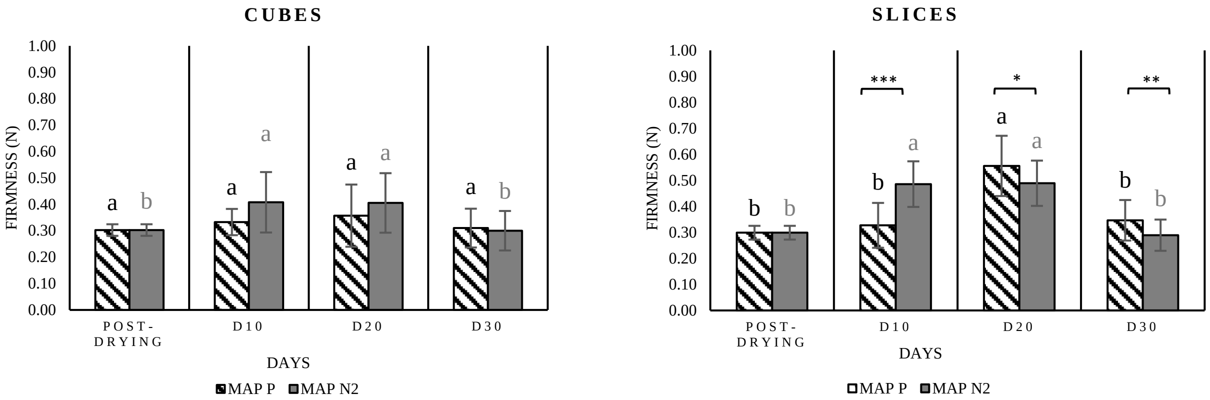

Figure 1. Firmness evolution of fruits Pescabivona var. Settembrina dried and stored for 30 days at room temperature (20 ± 1 °C). Values in the same set of histograms followed by a different letter are significantly different ($p < 0.05$); asterisks indicate statistically significant differences between MAP treatments with * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; no asterisks indicate a non-significant difference between the means of the treatments.

During the 30-day storage period, as can be seen from the results (Figure 1), the firmness (FF) of peach fruits varied significantly for MAP-N_2 C, MAP-P S and MAP-N_2 S treatments, although the S values were slightly higher than C values. However, no significant loss of firmness was found for S and C at the end of the 30-day storage period. Moreover, when comparing the two MAP treatments during the observations (D10, D20 and D30), significance was only found for the cut. The data show that although at D10 the MAP-N_2 packing positively influenced the maintenance of fruit firmness, the same behaviour was observed with the MAP-P treatment from D20 and D30. For this reason, we can state that storage in MAP-N_2 is not cost-effective for the Pescabivona supply chain.

The obtained data through the evaluation of firmness evolution can be compared with what emerged from the sensory analysis. As can be seen from Figure 4, firmness, as perceived through the FR descriptor, is evaluated positively for the entire storage period. In particular, the MAP-P S treatment maintains the values up to D30.

Similar results were reported by Tinebra et al. on behaviour of dried loquats [24]. Wu et al. [66] studied the firmness maintenance in dried fruit seeds, showing that N_2 plays a key role in maintaining organoleptic qualities. A study on the importance of N_2 was conducted on pomegranate arils [36], according to which, MAP was used to maintain the quality of the processed fruit and showed optimal results in terms of weight retention, which allowed the pulp structure to remain intact. A slight decrease in fruit firmness was observed during the storage period, attributable to the loss of turgor [35] and compensated by hardening due to drying. The results obtained are satisfactory when compared to studies conducted on peaches, pears and apricot [24], which lose up to 99% of their firmness values following drying.

3.4. Colour

The drying of fruit results not only in changes in the firmness but also in the characteristic flesh colour [65]. This occurs due to the oxidation of proteins and lipids and non-enzymatic reactions [68].

Table 3. Post-drying values of CIE L*a*b* coordinates that measure chroma and colour differences in both types of cuts (lightness (L*); redness (a*); yellow (b*); chroma (C*); colour differences (ΔE); dry residue (%DR). The data corresponds to the means ± SD.

	L*	a*	b*	C*	ΔE	%DR
Slices	72.38 ± 4.98	3.51 ± 2.17	38.90 ± 3.66	39.10 ± 3.80	16.12 ± 4.47	15.43
Cubes	73.25 ± 4.98	4.20 ± 2.17	40.22 ± 3.66	40.58 ± 3.80	17.91 ± 4.58	16.35

Figure 2. A representative sample of slices (a) and cubes (b) of Pescabivona var. Settembrina fruits after drying process.

Total colour differences (ΔE) after drying process showed similar browning between slices (S) and cubes (C) compared to the fresh unprocessed form (Table 3). These values are also confirmed by comparing L*, a* and b* values with Chroma. Therefore, temperatures and processing times did not cause significant variations between the two cuts (Figure 2). One possible reason could be that both cuts had similar amounts of initial moisture before drying process. In fact, when comparing the initial weights before drying, the two lots showed very similar values. This is also confirmed by the results of %DR (Table 3), which may have resulted to a similar drying process for both cuts.

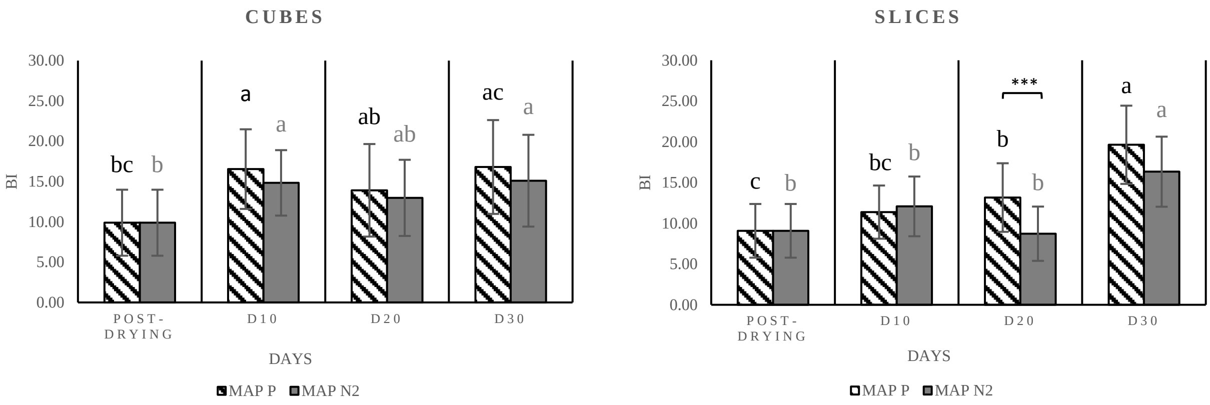

Figure 3. Browning Index (BI) values of dried Pescabivona samples were analysed during the experiment. Values in the same set of histograms followed by a different letter are significantly different ($p < 0.05$); asterisks indicate statistically significant differences between MAP treatments with *** $p < 0.001$; no asterisks indicate a non-significant difference between means of treatments.

However, different behaviour was observed during the 30-day storage in MAP (Figure 3). The measured data shows, in both types of cut, a significant increase ($p < 0.05$) in the browning index (BI) although, after 30 days of storage, the cut most that maintained the lowest BI values was the cubed cut. In S, there was an increase in BI of 10.56 in MAP-P and 7.26 in MAP-N_2 from the day after drying to D30. In cube cut, on the other hand, BI increased by 6.91 in MAP-P and 5.21 in MAP-N_2. In the presence of nitrogen, BI appeared to show an almost constant trend up to the last day of storage (D30) and, in all cases, maintained values closer to the first day of storage in MAP-P. Although variations in BI were observed in the two MAP treatments during the 30-days period, statistical analysis showed significance only for the slice at D20.

As can be seen from Figure 3, the BI values during storage do not differ much from those after drying. This shows that the pulp did not undergo significant changes in colouration. This phenomenon could be due to enzymatic processes mainly involving phenolic compounds [38]. Furthermore, there seems to be a positive correlation with both the time-temperature combination used and the immersion in antioxidant solutions carried out in the pre-drying phase. In addition, the presence of N_2, used to reduce the oxygen level within the package, inhibits the growth of aerobic microorganisms and prevents the oxidation of the nutrients present, thus preserving the quality of the fruit [69].

According to Wu et al. [66], in addition to maintaining firmness, N_2 is also responsible for less browning during storage. The results of this study showed that fresh peanut kernels treated with MAP N_2 maintained lower browning values than the control group during storage.

3.5. Sensory analysis

The sensory analysis of the dried products was conducted throughout the storage period, as shown in Figure 4. From the analysis of the results, the fruit was most appreciated for peach flavour (PF), sweetness (SW), juiciness (J) and crunchiness (CR). After 10 days of storage, the slices (S) stored in MAP-P were most appreciated, receiving scores of 7 in the positive descriptors of visual appearance (VA) and firmness (FR). In contrast, the cubes (C) stored in MAP-N_2 were found to be the sweetest but with a pronounced caramel flavour (CF) and more rubberiness (RU) than the other treatments. After 20 days of storage, fruit from all treatments was highly appreciated for sweetness (SW), rubberiness (RU) and visual appearance (VA). Finally, after 30 days of storage the peach cubes (C), stored in both MAP packaged, scored high for the negative descriptor browning (B), while the S fruit continued to have a very low browning value (B) and scored high for the positive descriptors sweetness (SW) and visual appearance (VA).

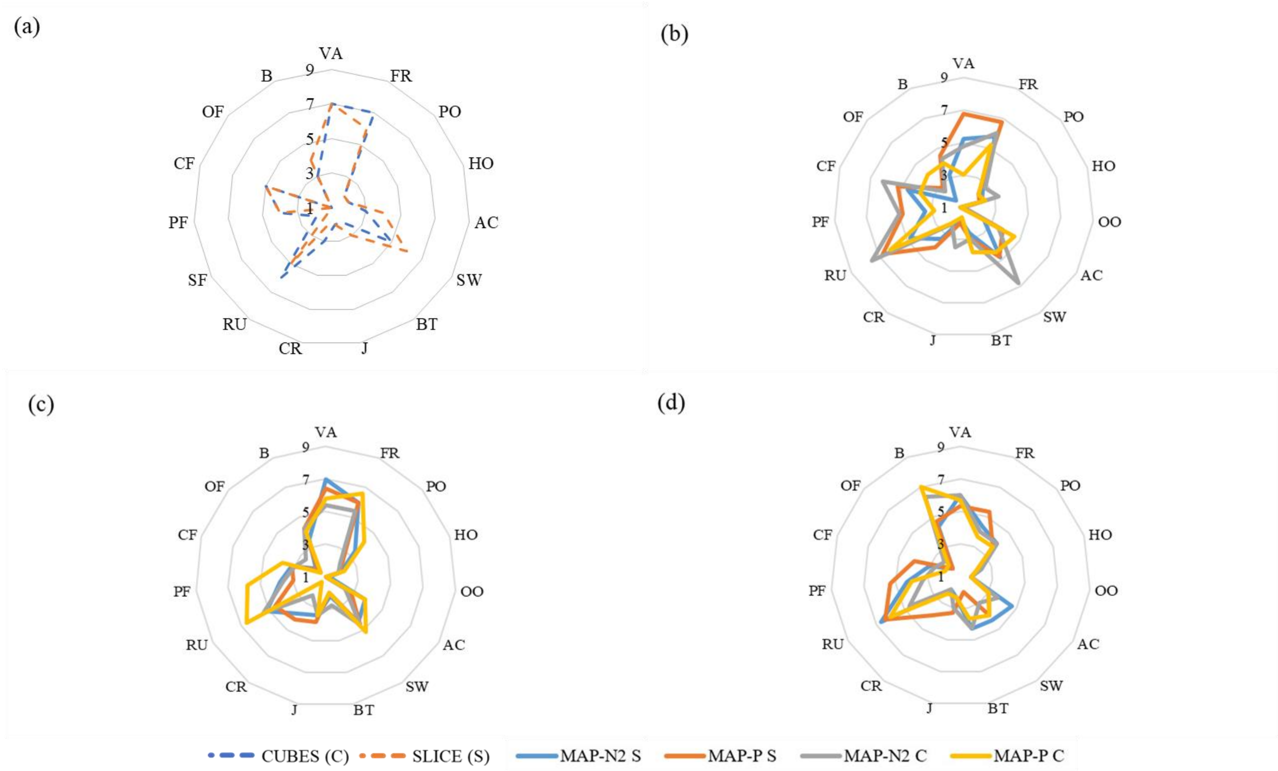

Figure 4. Results of sensory analysis conducted on Pescabivona var. Settembrina fruits dried at 0 (a), 10 (b), 20 (c), and 30 (d) storage days. Legend: visual appearance (VA); firmness (FR); peach odour (PO); honey odour (HO); off-odour (OO); acidity (AC); sweetness (SW); bitterness (BT); juiciness (J); crispness (CR); rubberness (RU); peach flavour (PF); caramel flavour (CF); off-flavour (OF); degree of browning (B).

4. Conclusions

In this study, the effect of MAP drying and storage on the physicochemical and sensory quality of Pescabivona var. Settembrina fruit was evaluated, with interesting results. The study concluded that it is possible to apply the drying process to white-fleshed peaches by identifying an appropriate time-temperature combination, which helps to maintain the quality characteristics of the fruit. Samples subjected to MAP maintained an attractive colour after drying and a good firmness and especially MAP-N_2 C treatments limited non-enzymatic browning during the storage. Sensory analysis showed that the slicing technique was the best choice, producing fruits with a good visual appearance and firmness, while the cube technique produced sweet fruits with a caramel flavour and more chewy firmness. Moreover, the tray-drying method could help recover Pescabivona var. settembrina fruit waste from the supply chain and create a new value-added- product.

Finally, there are no studies in the literature concerning tray drying of this fruit species. Therefore, this study is preliminary to future investigations concerning drying kinetics in order to more accurately assess the time interval in which a constant moisture value is obtained to preserve the organoleptic quality of the product in question. Furthermore, this approach could bring to light differences, in terms of time, between cubes and slices.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

Vittorio Farina is an editorial board member for AIMS Agriculture and Food and was not involved in the editorial review or the decision to publish this article. All authors declare that there are no competing interests.

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