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EFFECTS OF MODIFIED ATMOSPHERE PACKAGING ON QUALITY FEATURES OF 'FAVORIT' APRICOT CULTIVAR DURING COLD STORAGE

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Abstract

Apricots are stone fruit highly perishable and their limited post-harvest life is a problem for marketing. Low-cost postharvest techniques should be employed to extend the shelf life of fresh fruit and reduce postharvest losses. Apricots were packaged using 2 types of polypropylene films: microperforated and non-perforated and then stored at 1°C to study the effects of modified atmosphere packaging (MAP) on the maintenance of fruits quality and optimum storage time by comparison with non-wrapped fruits. Dry matter, weight, firmness, soluble solids content, titratable acidity, color, respiration rate, and ethylene production were evaluated. Apricots sealed in non-perforated plastic films at low temperature had an extended marketable life of around 15 days. Our results indicate that apricot fruit in non-perforated films showed lower weight loss, firmness and TA, as well as higher sugar content during storage. The respiration rate and ethylene production were lower in MAP package treatments than in control fruits.

Key words: *stone fruit, ethylene production, quality, low temperature, postharvest techniques.*

INTRODUCTION

Apricots are climacteric fruit with a limited postharvest storage to just a few days which is closely related to fruit variety. Their short storage life is often limited by high respiration rate and pronounced ethylene production and so rapid ripening process (Chambroy et al., 1995; Fan et al., 2000). This rapid deterioration usually leads to harvesting unripe fruits and therefore they cannot develop their organoleptic potential. Thus, in order to ensure a superior quality of the fruits with a sufficient storage potential, they must be harvested at the optimal maturity specific to this purpose. The use of cold storage may extend the shelf life of fruits; however, it may not be enough to preserve quality of apricots during storage, shipping and marketing.

Modified atmosphere packaging (MAP) has been found to be a successful method in delaying ripening, reducing water loss, ethylene production and softening, visible shriveling symptoms, and decay of different fruit during cold storage (Pretel et al., 2000; Amoros et al., 2008; Diaz-Mula et al.,2011; Aglar et al., 2017; Moradinezhad & Jahani, 2019; Ozturk et al., 2019; Aslanturk et al., 2022). In recent years, MAP has become widely used for fruit storage and shipping in fruit exporting countries (Phakdee & Chaiprasart, 2019; Palma et al., 2023).

The modified atmosphere increases CO_2 and decreases O_2 concentration around the fruit inside the packaging, thus slowing fruit ripening and stopping the growth of various microorganisms that cause diseases (Peano et al., 2014). Recently, Aslanturk et al. (2022) support that MAP treatments retarded weight loss, flesh softening, respiration rate and increase color of apricot fruit. Also, Moradinezhad and Jahani (2019) reported that the use of passive MAP effectively reduced postharvest losses of apricot fruits, and improved the qualitative and sensory characteristics of the fruit stored at 0.5°C for 28

days. Data of Ezzat (2018) showed the positive effect of MAP on reducing fruit weight loss and fruit firmness; fruit stored in MAP for 13 days showed the lowest fruit weight loss compared to control untreated.
Optimal storage duration of apricots depends on different factors such as the cultivar, the degree of ripeness at harvest, temperature, and air composition in MAP.
Therefore, the objective of this study was to evaluate the suitability of two films packaging and low temperature storage for quality maintaining of 'Favorit' apricot cultivar, originated from Romania and extend the postharvest life.

MATERIALS AND METHODS

The fruits of 'Favorit' apricot cultivar originated from Romania were harvested from the experimental orchard of Research Station for Tree Fruit Growing Băneasa, during two consecutive seasons. After harvesting, the fruits were rapidly transported to the laboratory where they were rinsed with tap water, drained and used for experiment. Fruits were packed on the same day of harvest in 25 µm polypropylene film and placed in 2 kg capacity plastic boxes. Each bag was sealed without gas packaging, so the modified atmosphere was established passively. The samples were stored for twenty days and analyzed at five days intervals.

Storage conditions

The fruits were divided into three groups, one for each storage condition. Three storage conditions of fruits were tested: refrigeration at 1ºC and 90% relative humidity without film (V1); MAP in non perforated films with refrigeration at 1ºC and 90% relative humidity (V2); MAP in microperforated films with refrigeration at 1ºC and 90% relative humidity (V3). Specific methods were used for each of the physical and biochemical parameters analyzed. Each variant was performed in four replicate.
Weight loss was determined by the difference between initial and final weights of each fruit during storage and expressed as percent.
Dry matter was measured by drying some slices from each side of equatorial part of fruits to a constant weight in an oven at 105°C. The results were expressed in percent (w/w).
Soluble solids content(SSC) were measured with a digital refractometer (Atago, Tokyo, Japan) at 20°C from juice extracted from the fruits, and expressed in °Brix.
Titratable acidity (TA) was quantified in juice by titration with 0.1N NaOH up to pH 8.1. TA is expressed as percent of malic acid which is the predominant acid in this species mg acid malic/100 g fresh weight. The ratio between the SSC/TA, which reflects the fruit taste feature, has been determined.
Acoustic firmness of fruits was measured at the equator of the unpeeled fruit in two repetitions using an AWETA Acoustic Firmness Sensor. In this device, an acoustic signal is generated by means of a gentle impact on the equator of the fruit. This signal is processed and transformed to obtain a peak of natural frequency, which is used to calculate the stiffness factor as $f^2 \times m^{2/3}$, where f represents this frequency and m is the fruit mass.
Color characteristics were measured at opposite sides of each fruit with a HunterLab MiniScan XE Plus spectrophotometer. Color was measured on the basis of the CIELAB color system. In this system L*, a* and b*, describe a three dimensional space, where L* is the vertical axis and its value varies from 100 for perfect white, to zero for black. Values a* and b* specify the red-green and blue-yellow axis, respectively ranging from -60 to + 60 or from –a (green) to +a (red) and from –b (blue) to + b (yellow). C* and h° values are calculated based on a* and b* values according to the following equation: $h^o = tg^{-1}\, b^*/a^*$ and $C^* = (a^{*2} + b^{*2})^{1/2}$.
The measurement of physiological parameters (respiratory activity and C_2H_4 concentration) was carried out following the closed-system method at 20°C (Chambroy et al., 1995). Apricots were placed in hermetic glass containers (1500 mL) equipped with rubber sampling ports. Three replicates were prepared from each maturity stage.
Concentration of CO_2 produced in respiration time of apricot was determined using an IR-RIKEN analyzer. Respiratory intensity of fruit was expressed in mg CO_2 kg^{-1} h^{-1}.
Concentration of C_2H_4 was determined using a Fisons GC 9000 series gas chromatograph with a flame ionization detector EL980 and a

Chrompack CP-Carboplot P7 column (inside diameter 0.53 mm, length 10 m). The temperature of the oven was 60°C and the detector temperature was 100°C. The carrier gas used was H_2. The values were expressed in µl C_2H_4 kg^{-1} h^{-1}.

RESULTS AND DISCUSSIONS

Apricot fruit quality after harvest, it damage very quickly, if special precautions are not taken and thus to meet an adequate quality, a combination of suitable storage conditions and a well-defined harvesting period must be met.

The quality of apricots after harvesting deteriorates very quickly if no special measures are taken, so in order to maintain an adequate quality, a combination of storage conditions and duration of storage must be met.

For these reasons, we chose the technology that allows keeping the fruits in an different atmosphere than the ambient one, namely modified atmosphere packaging. Inside the plastic box, fruit metabolism and especially respiration involves a decrease in the concentration of O_2 and an increase in the CO_2 concentration and humidity. Thus, the decrease in the concentration of O_2 is favorable for the induction of the slowing of the respiration rate and ethylene emission and thus the senescence of the horticultural product. The high concentration of CO_2 has an antagonistic effect on ethylene activity and also has fungistatic activity (Chambroy et al., 1995).

The obtained results indicate that weight, acoustic firmness, color, soluble solids and titratable acidity as well as physiological parameters give reliable indications of quality changes during storage. Apricots of the 'Favorit' cultivar without film change their color visibly during the first 5 days of storage. Thus, a decrease in the luminance value (L*) can be observed during the first 10 days of storage. This means a light color of the fruit (Figure 1). Also, studies of Aslanturk et al., (2022) and Muftuoğlu et al. (2012) reported that MAP - treated apricot fruit had a lower L* and chroma values. Peano et al. (2014) supported that after 21 days, apricots wrapped with the perforated film and fruits maintained under the normal atmosphere (control) lost brightness more than those in the polypropilen modified atmosphere packaging treatments, which exhibited lower *L** values of 55.2. At the end of storage, all treatments reduced the h^o values compared with the values observed at harvest. In fact, the highest h^o values (69.5 and 68.8) were maintained by films (V2 treatments), which corresponded to a high water vapor barrier.

Regarding the a* parameter, its values increase progressively from 12.59 at harvest to values of 27.14 after 5 days of storage, which denotes an orange - red color. During the next 5 days of storage, a slight decrease of this parameter was observed up to values of 23.63. The yellow parameter (b*) has increased values since harvesting around 49.06, which denotes an intense yellow degree and a yellow-orange color of the fruit, which is maintained during the first 5 days of storage, after that a slight decrease is observed up to around 42.5 (Figure 1).

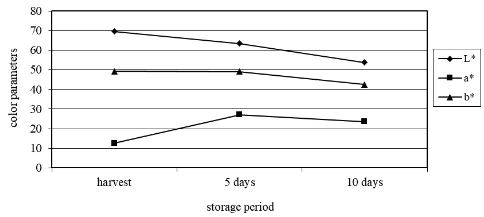

Figure 1. Color parameters variation during the storage apricot fruits without film

For fruits covered with perforated film (Figure 2), the a* parameter increases during storage but more slowly reaching higher values (28.20) compared to the variant without film and therefore the fruits have a more intense degree of red. The parameter b* increases slightly during the first 5 days of storage, after that, it slowly decreases during the last 10 days of storage, which once again supports a pronounced yellow-orange color.

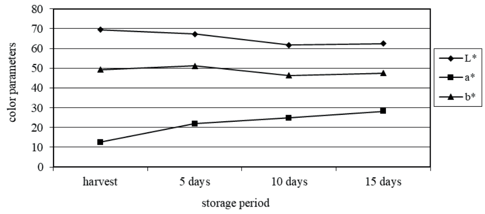

Figure 2. Color parameters modification during the storage apricot fruits with perforated film

The value of the L* parameter decreases slowly during the 15 days of storage, the color becoming increasingly lighter. In the case of the condition with non-perforated film (Figure 3), the same pattern of changes in color parameters can be observed as in the case of the perforated film, with the mention that the a* parameter increases slightly during the first 5 days of storage and remains almost unchanged during the next 10 days.

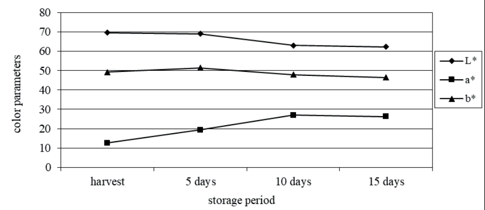

Figure 3. Color parameters modification during the storage apricot fruits with non-perforated film

Among the color components L*, a*, b* of the fruits, the a* parameter shows significant variations among the studied variants. The values of b* change much less during storage and sometimes remain constant. No consistent change in the value of the C* parameter was detected during apricot storage. The values of the h° parameter decrease during apricot storage, these results being in accordance with those obtained by Fan et al. (2000).

The shape of the spectra of the 'Favorit' cultivar is generally similar in the case of the three variants studied, usually having a maximum at 610 nm (at harvest) and one at 640 nm after 5 days of storage) after 10 and 15 days of storage a single maximum at 640 nm remains, which implies that the fruits have reached the maximum color of a ripe fruit (Figure 4, Figure 5).

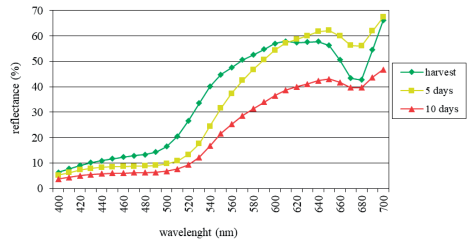

Figure 4. Reflectance spectra's modification during the storage apricot fruits without film

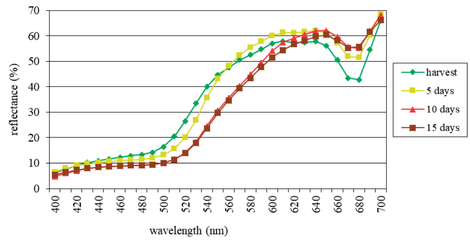

Figure 5. Reflectance spectra's modification during the storage apricot fruits with non-perforated film

Regarding acoustic firmness (Table 1), it decreases strongly for uncovered fruits and slowly for those covered with film. It is observed that the fruits covered with non-perforated film maintain an increased firmness even after 15 days of storage compared to those without film where the firmness drops to values close to zero (0.8) even after 10 days of storage. The effects of the modified atmosphere in maintaining fruit firmness, delaying fruit softening and increasing shelf life have also been reported for other climacteric fruits (Agar and Polat, 1995; Gouble et al., 2006; Jay et al., 2006; Antunes et al., 2007; Infante et al., 2008). Peano et al. (2014) supported that after 21 days, the apricot flesh firmness values in modified atmosphere packaging were similar to those of control fruits.

Table 1. Evolution of some quality parameters of 'Favorit' apricot variety during storage in MAP at 1°C

Variety	Storage period (Days)		Dry matter %	Weight loss %	Acoustic Firmness	SSC °Brix	Titratable acidity mg malic ac. %
'Favorit'	0 (harvest)		17.87	0	4.4	16.2	1.1
	5	V1	15.93	14.1	1.7	15.5	0.98
		V2	12.72	15.5	3.3	12	1
		V3	13.81	18.5	2.5	13.1	0.96
	10	V1	13.45	29.3	0.8	13	0.95
		V2	12.12	16.7	2.8	12.2	0.98
		V3	13.2	19.8	1.2	13.3	0.95
	15	V1	14.2	41.2	0.4	8.2	0.98
		V2	12	23	2.1	11.8	0.87
		V3	12.8	26.2	0.9	12.7	0.82

However, the highest values were observed for fruits stored with multilayer films, which maintained the highest state of hydration and the highest CO_2 concentrations.

The weight of the fruits of the 'Favorit' cultivar covered with film gradually decreased much more slowly than those without film (Table 1). In uncovered fruits, the weight loss was strong in the first 10 days of storage but also linear, and after 15 days of storage they had a wilted and uncommercial appearance. The difference between the weight loss of fruits covered with different films is probably due the speed of water vapor transmission through the film. In the same way as the weight, the total dry matter also varies during fruit storage (Table 1). This has high values at harvest of 17.87% and decreases to around 12% or 12.8% after 15 days of storage for the variants covered with the two types of films.

Post-harvest changes in fruit weight during storage are due to water loss through transpiration, which leads to withering and shriveling of the fruit (taking into account that apricots do not have a waxy skin) which reduces the commercial value and consumer acceptability. Apricots stored in the modified atmosphere show a significantly lower weight loss (three times lower) than the control without film. Non-perforated film and low temperature can prevent excessive fruit weight loss. Our results agree with the results of Agar and Polat (1995) and Antunes et al. (2007) who found that apricots stored in modified atmosphere lost about 3% of their weight after 18 days, while the control without foil lost 8%. Several studies also reported retarded weight loss with MAP treatments (Diaz-Mula et al., 2011; Muftuoğlu et al., 2012; Peano et al., 2014; Ezzat, 2018; Aslanturk et al., 2022). Results of Dorostkar et al. (2022) showed that apricot fruit weight remained stable during storage under active MAP treatments, whereas control samples showed an average weight loss of about 6-fold higher than MAP samples after 28 days.

The soluble solid content (Table 1) decreases slowly during the storage of the fruits both in those covered with film and in those not covered. It decreases linearly from values of 16.2°Brix at the time of harvesting to values between 11.8°Brix and 12.7°Brix after 15 days of storage. These results are consistent with those of Chira et al. (2020) and Jay et al. (2006), but are contradictory to those of Agar and Polat (1995) and Ishaq et al. (2009) who support the increase in soluble dry matter content during apricot ripening. These values as well as the titratable acidity indicate a balanced taste for the fruits of this cultivar covered with film even after 15 days of storage. This may be due to the dehydration of the fruit or the increase in respiration rate and the conversion of sugars into CO_2 and H_2O at the end of storage. It is interesting that after the postharvest ripening, the fruits do not reach the same refractometric index (sugar/acidity ratio) as those harvested at horticultural maturity.

The amount of fruit acids during storage varies similarly for all tested variants. It decreases progressively almost linearly in all cases, although the rate of decrease was higher in the case of the variant without film. These trends are consistent with those reported by Infante et al., (2008) and Jay et al. (2006) for peaches and with those of Agar and Polat (1995) for apricots. Organic acids are substrates for respiration and the modified atmosphere reduces respiration (Ishaq et al., 2009) therefore slowing down the metabolism of organic acids. However, Jay (2006) says that the decrease in acidity during storage was limited. During the storage of 'Favorit' apricots the acidity decreases, but some samples do not reach the acidity of those picked mature.

The concentration of ethylene in the 'Favorit' phenotype increases progressively (Figure 6) in all variants up to 10 days of storage, the most intense in the variant without film. After 15 days of storage for the variants covered with film, the rate of ethylene production increases very slightly, being almost constant.

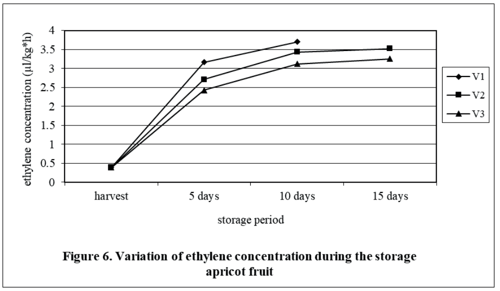

Figure 6. Variation of ethylene concentration during the storage apricot fruit

The evolution of respiration during the storage 'Favorit' fruits is almost similar to the variants covered with film, this having a maximum after 10 days of storage, after which it drops visibly after 15 days of storage. However, in the uncovered variant, the respiratory intensity increases continuously up to 10 days of storage (Figure 7).

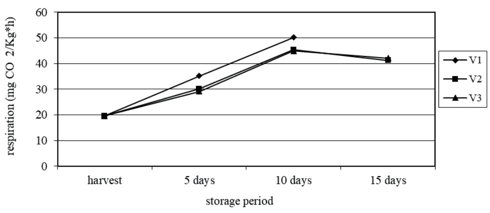

Figure 7. Variation of respiration intensity during the storage apricot fruits

Chira et al. (2020) supported that the optimal duration (14-20 days) of fruit storage varied for every apricot cultivar studied according to the moment of fruit harvesting and storage condition (MAP or low temperature), they highlights that the fruit harvested at the ripening phase had a longer storage period.

CONCLUSIONS

In essence, it is observed at this cultivar that the variant without film storage averages 10 days when the fruits have a color that allows industrial processing rather than fresh marketing due to the very low firmness.

Use of the two types of film makes this cultivar have a longer storage period and even after 15 days it has a pleasant commercial appearance with a yellow-orange color and an adequate firmness, around 2.1, with a balanced taste.

Nonperforated film represent the best packaging materials to store 'Favorit' apricot cultivar in modified atmosphere packaging for limiting weight loss, maintaining the firmness and the color of fruits.

The obtained results highlight the fact that the fruits of the variant with non-perforated film had the longest shelf life, followed by the variant with perforated film and then the non-covered one.

MAP treatments could be used as an efficient tool to prevent or minimize the apricot quality losses throughout the cold storage period

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