CHEMICAL ENGINEERING TRANSACTIONS
VOL. 58, 2017

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Remigio Berruto, Pietro Catania, Mariangela Vallone

ISBN 978-88-95608-52-5; **ISSN** 2283-9216

DOI: 10.3303/CET1758067

Quality Changes of Tropical and Subtropical Fresh-Cut Fruits Mix in Modified Atmosphere Packaging

Giuseppe Sortino, Valeria Caviglia, Giorgia Liguori, Claudio De Pasquale*, Giuseppe Gianguzzi, Vittorio Farina

Department of Agricultural and Forest Sciences, Università degli Studi di Palermo, Palermo, Italy
claudio.depasquale@unipa.it

Application of passive modified atmosphere packaging (MAP) for shelf life extension of mixed pineapple slices, mango pieces and orange segments, was evaluated. Fruits of Ananas cv 'Gold', Mango cv 'Keitt' and Orange cv 'Washington Navel' were washed, sanitized, peeled and cut. Minimal processed fruits were packed under 2 different atmospheres, passive (air) and active MAP (70% N_2, 10 %O_2, 20 %CO_2), and stored at 10±1 °C with 85±5% RH for 12 days. Changes in package atmosphere composition, weight loss, color, texture, pH, soluble solids, sensory attributes, were evaluated after cutting and at three subsequent stages of storage (the 3 day, 6d, 9d, and the 12 day). Color parameters L* and b* significantly decreased over time in all packaging conditions and L* variation was directly attributed to the translucency phenomenon in the fruit flesh. The pineapple and orange parameters highlighted the best visual score during the storage period, the lowest values of the browning index and the highest scores of all sensory descriptors at each sampling date. Organoleptic attributes have not been influenced by the storage time and no off-flavors were detected in the treated fruit. We conclude that pineapple slices and orange segments can be maintained in excellent condition for up 9 days at 10±1°C following the treatment with active MAP.

1. Introduction

The increased awareness of consumers on the benefits of fruit consumption for health and the increased interest in the ready-to-eat fruits, have powered the enlargement fresh-cut products market in the last decade (Oms-Oliu et al. 2010; Allegra et al. 2015a). In Europe the citrus sector was affected by this modified demand, and the European Agricultural Policies supported the citrus sector, encouraging the consumers to purchase minimally processed fruit in addition to the fresh fruit. According to recent studies, Sicily is the first Italian citrus's production pole (citrus production is 15% of value of all agricultural production base-price of Sicily). The umbilicated orange, cultivar 'Washington Navel' (*Citrus sinensis*), is a niche product cultivated in the province of Agrigento (Southern Italy), which is characterized by blonde-pulp and sweet taste. This cultivar achieved in 2008 the certification "Protected Designation of Origin" (PDO), namely, "Arancia di Ribera" PDO, Reg. CE n.95/2011 (alias Ribera's PDO), thanks to its high organoleptic content and its fine taste (Ingrassia et al. 2016). The production regulations specify the mandatory parameters to protect the quality attributes of the "Ribera's PDO". Pineapple (*Ananas comosus*) is the world's most popular non citrus tropical and subtropical fruit. Currently, 'Gold' is the most accepted cultivar around the world. This cultivar has cylindrical shape, square shoulders, an intense orange-yellow shell color and a medium to large size (1.3–2.5 kg), and stands out for its excellent quality and sensory characteristics. Mango (*Mangifera indica* L.) is the major fruit crop in tropical and subtropical regions. Its production is reported in more than 87 countries with an estimated production of 42,000 t year and it is expected to increase in the next future. In the last decades, mango cultivation has been moving outside the traditional geographical regions and it is now largely cultivated in the Mediterranean area, particularly in Italy, along the coastal line of Sicily island (Liguori et al. 2017). Application of modified atmosphere packaging (MAP), in combination with low temperature storage, for shelf life extension, has been extensively studied for a vast variety of fruit products in the last years, but much research is still to be done in order to develop fresh-cut fruit mix products with high sensory quality and nutritional value,

Please cite this article as: Sortino G., Caviglia V., Liguori G., De Pasquale C., Gianguzzi G., Farina V., 2017, Quality changes of tropical and subtropical fresh-cut fruits mix in modified atmosphere packaging, Chemical Engineering Transactions, 58, 397-402
DOI: 10.3303/CET1758067

safe for the consumer (Oms-Oliuet al. 2010; Liguori et al., 2015). This work aimed at evaluating physicochemical and sensory changes of minimally processed mix fruits packaged with active and passive atmosphere, during storage at 10 °C for 12 days, in order to know the fruit mix's behaviour and the best packaging conditions to extend the shelf life of these fruits.

2. Materials and Methods

Fresh 'Gold ripe' pineapples (*Ananas comosus* L. Merrill), imported from Costa Rica, were bought at a local supermarket of the Conad supply chain in Palermo, Italy, at shell color stage (approximately 10–15 days after harvesting, at 7–10°C during transport). Shell color stage was where several to most of the shell eyes were partially filled with yellow color, all of them surrounded by green (Po and Po, 2012). Fruits were stored at 5±1°C overnight prior to processing. Late ripening mango fruit cv *Keitt* was harvested from a commercial orchard, located at Furiano, (Sicily, ME), Italy; 38°3' N, 14°33' E; 5 m a.s.l.). Fruit was hand picked at the mature-ripe stage (full ripe), suitable for the fresh fruit market, using skin color as maturity index. Oranges (*Citrus sinensis* L. Osbeck, cv. *Washington Navel*) were harvested at maturity stage from a private orchard, located in the "Arancia di Ribera" PDO area. Fruits were selected in uniformity of weight, size, maturity stage and absence of physical injuries. Working area, cutting boards, ceramic knives, boxes and other utensils and surfaces in contact with the fruit during processing were washed and sanitized with 200 ppm sodium hypochlorite solution at pH 7 to have a maximum sanitizing effect prior to processing. The peeled mangoes were submerged in a second sodium hypochlorite solution (1.3 mM) at 5 °C for 1 min, and left to drain until they were processed (5–15 min). Subsequently, the slices were drained for 2 min before being distributed into the storage boxes as previously explained. For Pineapple crown leaves were removed and the fruit was washed twice in two 200 ppm sodium hypochlorite solutions for 5 min each, letting excess water drain for 3–5 min (Allegra et al, 2016).Then fruit was peeled and cut into 1 cm-thick piece using an cutting machine (Food Slicer-6128: Toastmaster Corp, Elgin, USA). Slices were then cored and cut into wedges (6–8 g, each) with sharp knives. Oranges were sanitized by immersion for 2 min in 200 ppm Cl_2 then rinsed with distilled water, air-dried, and manually peeled. Subsequently, fruits were manually processed in segments. Each box, containing 4 orange segments (about 180 g). The fruits were placed in non-perforated high density polyethylene packages (90 µm PP bags 20 × 30 cm; O_2 film permeability <65cm³/(m² * 24 h * atm), (23 +/- 2 °C); CO_2 film permeability: <200 cm³/(m² * 24 h * atm), (23 +/- 2 °C); H_2O film permeability: <5 g/m²/24h, (23 +/- 1 °C), using a Supervac GK105/1 packaging machine (Orved, Italy), flushed with a gas mixture to reach different active and passive MAPs, hermetically sealed and then kept at 10°C for 12 days. We used a different gas partial pressure for each treatment: 70 kPa N_2, 20 kPa CO_2, 10 kPa O_2 (MAP) and passive MAP (CTR). With regards to gas analysis the atmospheres inside all of the MAPs were measured at each stage (0, 3, 6, 9 and 12) with an O_2-CO_2 gas analyzer (CheckPoint Portable Headspace Analyzer, PBI Dansensor, Ringsted, Denmark). *C*olor was measured directly with a Minolta CR-400 chroma meter (Konica Minolta Sensing, Inc. Osaka, Japan), using the CIE scale *L** *a** *b**. Readings were made by directly applying the chroma-meter head onto the surface of the fruits tissue. Firmness of fresh-cut slices or segments was measured using an Instron Universal Testing Instrument (Model 4411) fitted with a 1-cm-diameter convex probe, and equipped with a 50 kg load cell. The results were expressed in Newton (N). The soluble solids measurements were performed using a portable hand held brix (%) refractometer, RX- 1000 (Atago Company Ltd, Japan). The pH measurements were performed using a pH meter Crison 2001 (Crison Instruments S.A., Barcelona, Spain) and 10–15 g of filtered pulp were titrated with 0.1N NaOH to pH 8.1. Titratable acidity was expressed as grams of anhydrous citric acid in 100 g of fruit fresh weight.. Total phenolic content was determined. 2 g of homogenized sample were added with 10 ml of pure ethanol. The extraction was done by using a vortex mixer mod. RX3 for 60 seconds. The mixture was filtered and the filtrate was taken into a test tube. The Folin-Ciocalteau micro method of Waterhouse (Brand-William et al., 1995) was used to determinate the total phenolic content (TPC). 60 µl of the filtrate were diluted in 4,8 mL of Milli-Q grade water, and 300 µl of Folin-Ciocalteau reagent was added and shaken. After 8 min, 900 µl of 20% sodium carbonate solution was added with mixing. After reaction at 40°C for 30 min, absorbance was measured at 765 nm using SHIMADZU UV mini- 1240 spectrophotometer. A calibration curve of gallic acid (3, 4, 5- trihydroxybenzoic acid) was prepared (0 - 50 µg) and used as standards. The results were expressed as mg gallic acid equivalent per gram of fresh weight. The free Radical-scavenging activity of 1,1-diphenyl-2-picrylhydrazyl radical (DPPH) were measured in terms of their radical-scavenging ability (RSA), using the DPPH method (Brand-Williams et al., 1995; Padmanabhan and Prince, 2012). Aliquots of the whole juice were mixed with an ethanol solution of DPPH (3 mM), namely 2.37 mg DPPH in 2 mL ethanol. For the sample solution, 28 µL whole juice was mixed with 28 L DPPH solution and 944 µL ethanol. After incubation in the dark at room temperature for 10 min, the spectrophotometric determination was assayed at 515 nm using a spectrophotometer (CELL, model CE 1020). A freshly prepared DPPH blank solution (containing 972 µL ethanol and 28 µL DPPH solution) was used. The DPPH solution was stored in a flask covered with aluminum foil, and kept in the dark at 4°C between measurements. The percentage decrease in absorbance was recorded for each sample, and percentage quenching of DPPH radical was calculated on the basis of the observed decrease in absorbance according to the formula: % Inhibition =[(A0 – A1) /A0] x 100 where A0 is the absorbance value of the DPPH blank solution and A1 is the absorbance value of the sample solution. Fruit was evaluated by a semi-trained sensory panel (9 members, ages ranging from 22 to 55 years old) using a descriptive test and a 1-9pt rating scale were 1 = worst and 9 = best (Sortino et al. 2015). All panelists were trained and developed a wide expertise in sensory evaluation of fruits (Farina et al., 2016), and, before the beginning of the sensory experiments they were familiarized with the product and scoring methods. To achieve consistency, demonstration exercises were carried out examining samples of fruits with different levels of deterioration and agreeing appropriate scores for each of the parameters evaluated (Allegra et al., 2015b; Liguori et al 2014). The analyses were performed weekly, with controlled conditions of temperature (20±2 °C), relative humidity (80%) and illumination (artificial source of fluorescent light, simulating daylight). Samples of the different treatments were presented in groups, coded with random numbers. During the main experiment, for each storage condition, two pieces or segments of fruit (two for orange, two for pineapple and two for mango) were presented to the panelists in closed odorless plastic containers labeled with three-digit random numbers at room temperature (Sortino et al., 2016). Data analysis was performed through a one-way analysis of variance (ANOVA) to evaluate the significance of differences between storage times, using the Systat software v.13. The mean values of each variable were compared using Tukey's mean separation test ($P \leq 0.05$).

3. Results and Discussion

Weight loss of fresh-cut MAP fruit increased gradually during 12 days of cold storage, especially in CTR fruit that showed higher values than MAP treatment (Table 1). More particularly, at 12 days weight loss was 3.81% in mango CTR boxes respect to 2.88 %, and 1.40 % of pineapple CTR and Orange CTR, respectively (Table 1). After 3 days at 20 °C, fruit weight loss showed a similar behavior, with values of 4.42 % in mango CTR, respect to 3.11%, and 1.65% for pineapple CTR, and orange CTR. These results confirm that active MAP, created within the boxes, reduced weight losses in packaged fresh-cut 'Keitt' mango fruit slices, as also reported in "Tommy Atkins" mango fruit by Cocozza et al. (2004). TSS content did not change relevantly in CTR and MAP fresh cut boxes during the first 3 days of cold storage at 10°C (Table 1). However, after 6 days, CTR showed a marked and significant reduction in TSS compared to MAP samples (Table 1). After 12 days of storage plus 3 days at 20°C (3d Shelf-life), MAP bags showed a higher TSS content than CTR with values of 15.69% (Mango), 12.13% (Pineapple), and 10.68% (Orange) respectively (Table 1). Differently than TSS, TA was generally stable over the whole course of the experiment and differences among treatments were low. Firmness is another important attribute of fresh-cut fruit, often used for assessment of quality consistency of all fruit destined for the minimal processing, in this study, texture of Map and CTR did not change significantly for 6 days of storage. As a result of wounding by cutting, the CO_2 production rate increased the first day after cutting. In treated slices (MAP), however, the increase was less than in non-treated slices (CTR). In-package CO_2 increased during cold storage and during the shelf-life period in all treatments (MAP 70 N_2, 10% O_2, 20% CO_2 and CTR AIR). Despite in MAP +3d SL packages changes were very slight in cold storage and peaked to 33.6% after 9 days, in CTR and CTR +3d SL samples the levels of CO_2 increased dramatically after 3 days (CO_2 8.9 %), with values in both treatments significantly higher than those initial. At the end of cold storage the CO_2 partial pressure was 30.3 and 19.6% in Map and CTR, respectively, and further increased in shelf-life conditions with final values of 33.4% in MAP + 3 d SL and 18.9 % in CTR + 3d SL. The higher level of CO_2 production rate in control can be related to tissue stress which is caused by the processing such as cutting (wounding). The in-package levels of O_2 were complementary to CO_2: in MAP and MAP+ 3d SL packages values slightly declined with storage and shelf-life and ranged between 8% and 6%; in CTR and CTR +3d SL packages the partial pressure was always below 15.9 % (Data not shown). The provision of the colorimetric characteristics during the 12 days of storage showed a decrease of the L * a * b * values for mango fruit slices in all MAP and CTR treatments. MAP packaging positively influenced the values of b *. It was observed a similar trend during the 3 days (3d SL) after 6 days of storage at 10 °C. More particularly, after 3 days of shelf life at 6 day of storage, CTR adversely affected all the color coordinates, and after 9 days only L * and b *. Finally, MAP showed a positive effect of the treatment on the values of L * compared to CTR. Pineapple measurements of L (brightness) and b (browning or loss of yellow color) values clearly showed different degrees of browning on the cut surfaces suppression. The slices of processed values were reduced slightly, after 6 days of storage at 10°C, and were significantly different from CTR slices. After the same period of storage, there was a marked decrease in the lightness of CTR slices and differences with MAP increased after 6 days of storage. These slices maintained superficial brightness and good aesthetic appearance. The extent of the color changes in the present study for L * and b * agree with those obtained by other authors during storage (González-Aguilar et al., 2004; Montero et al., 2009).

Table 1:Total soluble solid (TSS), titratable acidity (TA), weight loss and firmness of fresh-cut of mango, pineapple and orange during 12 days at 10°C and 90% RH and additional 3 days.

			TSS (%)		**TA (%)**		**Weight loss (%)**		**Firmness (N)**	
			AS*	**3d SL****	**AS***	**3d SL****	**AS***	**3d SL****	**AS***	**3d SL****
Mango	**0**	Map	17.59±0.5a	16.72±0.4a	0.60±0.09a	0.59±0.04a	0.00±0.0d	1.91±0.4d	45.7±0.9a	41.5±0.4a
		CTR	17.59±0.5a	16.72±0.4a	0.60±0.09a	0.59±0.04a	0.00±0.0d	1.91±0.4d	45.7±0.9a	41.5±0.4a
	3	Map	16.92±0.8ab	16.85±0.5a	0.61±0.05a	0.60±0.03a	1.74±0.1c	2.15±0.7c	38.1±1.0b	30.6±1.2b
		CTR	16.52±0.6b	16.03±0.5b	0.59±0.02a	0.60±0.01a	1.96±0.4c	2.65±0.5c	34.1±0.8b	25.6±1.1b
	6	Map	16.53±0.7b	15.85±1.0c	0.63±0.07a	0.58±0.02a	2.22±0.1b	3.22±0.4b	33.7±0.4b	26.2±0.9b
		CTR	15.89±1.1c	14.77±0.8c	0.60±0.07a	0.56±0.03a	2.62±0.1b	3.97±0.4b	31.1±0.5b	20.3±0.8c
	9	Map	16.05±0.4a	15.75±0.4c	0.56±0.06a	0.53±0.05b	3.10±0.1a	3.73±0.4b	20.5±0.5c	16.8±0.7c
		CTR	15.81±0.7c	15.45±0.9c	0.54±0.05a	0.52±0.02b	3.42±0.5a	4.95±0.9a	18.8±0.7c	13.6±0.4c
	12	Map	15.74±0.6c	15.69±0.7c	0.51±0.03b	0.55±0.08ab	3.33±0.1a	3.97±0.9a	18.7±0.7c	13.7±0.2c
		CTR	15.57±0.8c	15.33±0.9c	0.50±0.01b	0.50±0.02c	3.81±0.1a	4.42±0.7a	15.9±0.7d	11.0±0.5d
Pineapple	**0**	Map	14.65±0.3a	13.95±0.5a	0.69±0.03a	0.67±0.02a	0.00±0.0e	1.05±0.4d	41.8±0.7a	40.2±0.3a
		CTR	14.65±0.3a	13.95±0.5a	0.69±0.03a	0.67±0.02a	0.00±0.0e	1.09±0.3d	41.8±0.7a	40.2±0.3a
	3	Map	14.80±0.4a	13.77±0.4a	0.65 ±0.02a	0.63±0.01b	0.80±0.2d	1.47±0.2c	39.3±0.4a	35.1±0.4b
		CTR	14.58±0.8a	13.23±0.5a	0.64±0.04a	0.63±0.05b	0.89±0.2d	1.58±0.4c	37.2±0.5a	32.5±0.6b
	6	Map	14.22±0.3a	13.15±0.2b	0.58 ±0.05b	0.56±0.04c	0.98±0.3d	1.79±0.2c	36.5±1.1a	34.5±1.5b
		CTR	13.83±0.5b	12.58±0.6b	0.57±0.02b	0.56±0.02c	1.23±0.5c	1.99±0.6b	32.8±0.9b	31.4±0.8c
	9	Map	13.85±0.5b	12.49±0.4b	0.56±0.03b	0.55±.0.02c	1.46±0.2c	2.10±0.2b	33.8±0.9b	31.9±0.9c
		CTR	13.59±0.6b	12.40±0.4b	0.55±0.02b	0.54±0.01a	1.69±0.4b	2.41±0.8b	28.1±1.2bc	25.3±0.4d
	12	Map	13.41±0.2bc	12.13±0.3b	0.50 ±0.01c	0.46 ±0.05d	1.95±0.4b	2.55±0.4b	26.9±0.4c	23.9±0.6d
		CTR	13.02±0.5c	11.89±0.7c	0.48±0.02c	0.47±0.01d	2.88±0.4a	3.11±0.4a	22.2±0.4d	19.1±0.4e
Orange	**0**	Map	11.32±0.7a	11.25±0.5a	0.85±0.05a	0.84±0.03a	0.0±0.0e	0.0±0.0a	33.2±0.4a	33.9±0.2a
		CTR	11.32±0.7a	11.25±0.5a	0.85±0.05a	0.84±0.03a	0.0±0.0e	0.0±0.0a	33.2±0.4a	33.9±0.2a
	3	Map	11.31±0.5a	11.18±0.3a	0.86±00.2a	0.85±0.04a	0.54±0.3d	0.74±0.3a	30.0±1.1a	28.2±0.5b
		CTR	11.10±0.3a	11.05±0.8a	0.85±0.03a	0.86±0.05a	0.85±0.2c	0.97±0.5	28.3±0.6ab	27.1±0.5b
	6	Map	11.32±0.2a	11.33±0.5a	0.85 ±0.02a	0.84±0.03a	0.95±0.2c	1.03±0.2a	29.8±0.7ab	26.4±0.7b
		CTR	11.20±0.5a	11.00±0.3a	0.83±0.03a	0.83±0.01a	1.22±0.3ab	1.43±0.5	27.3±0.3b	24.6±0.3b
	9	Map	11.10±0.7a	11.11±0.2a	0.82±0.05a	0.81±0.02ab	1.10±0.3b	1.23±0.3b	26.5±0.8b	23.5±0.4b
		CTR	10.89±0.3b	10.75±0.5ab	0.80±0.03ab	0.78±0.03b	1.26±0.7a	1.49±0.3	23.6±0.7c	21.1±0.5b
	12	Map	10.93±0.6b	10.68±0.4b	0.77±0.05b	0.78±0.03b	1.29±0.6a	1.54±0.9b	20.9±0.8d	18.9±0.4c
		CTR	10.82±0.3b	10.55±0.3b	0.73±0.03b	0.74±0.01b	1.40±0.4a	1.65±0.3	18.3±0.6d	17.2±0.5c

** AS= Values registered immediately after storage at each stage (0, 3, 6, 9, 12 d) at 10 °C; ** Values registered after storage at each stage (0, 3, 6, 9, 12 d) plus further 3 days to simulate the shelf life at 20 °C. For each cultivar, means followed by the same letter in each column are not significantly different at P ≤ 0.05, according to Tukey's test.*

Pineapple average values L* increased from 69.9 and 73.6 (3d SL) at the beginning of the experiment to 57.1 and 63.3 (3d SL) after 12 days of storage at 10°C, and the values of b* changed from 34.7 to 37.5 up to 31. These color differences L* a* b* were mainly attributed to the observed changes in translucent appearance of the tissue, which changed from a yellow-white opaque color to a translucent yellow color (Montero et al., 2009). Orange average values L* increased from 53.4 and 54.6 (3d SL) at the beginning of the experiment to 48.2 and 48.9 (3d SL) after storage 12 d 10°C, and the values of b* changed from 22.4 to 24.6 up to 21. Results show that orange fruit is the one with less color variation compared to mango and pineapple, especially with regards to the parameter L. Polyphenol content, immediately after cutting was significantly different in the three types of samples of fruit analyzed, rating 12.62 mg L^{-1} for mango, 14.69 mg/L^{-1} for pineapple and 26.65 mg/L^{-1} for orange. Then the values of all samples decreased until the 12th day of storage, in fact we detected 8.39 and 6.39 mg L^{-1} for mango Map and CTR, 9.42 and 8.42 mgL^{-1} for pineapple Map and CTR, 22.79 and 20.39 mg/L^{-1} for Orange Map and CTR. (Figure 1). The behavior of the antioxidant activity during the 12 days of storage is similar on all samples analyzed. The rating after cutting is 54.72% for mango, 68.52 % for pineapple and 89.99% for orange. Then the values decreased until the 12th day of storage, with results of 34.66% (MAP) and 30.51% (CTR) for mango, 57.45% (MAP) and 53.38% (CTR) for pineapple, 47.57% (Map) and 44.54% (CTR) for Orange (Data not shown). Sensory results from the trained panel (Table 2) proved that this fresh-cut mix had good characteristics for consumption because of the high intensities of several key attributes. As for appearance characteristics with Map ranged from 8.4 to 5.1 for mango, from 8.7 to 6.6 for pineapple, and from 8.5 to 6.0 for orange. For the CTR samples, judges expressed a low result compared to the Map fruit, for all times, observed score ranged, during 12 days, from 8.4 to 4.0 for mango, from 8.7 to 5.3 for pineapple and from 8.5 to 5.8 for orange. The same behavior was observed for odor and flavor descriptors. Particularly, Map samples ranged from 8.8 observed for odor attribute of mango odor, to 6.0 observed for flavor of pineapple. Generally, increased storage time lead to a decrease of all descriptors of the odor, and an increase in intensity of aged odor, artificial odor for all the test samples. However, since the presence of strong odor was noted by panelists we can say that there was no microbial deterioration in both the MAP and the CTR samples.

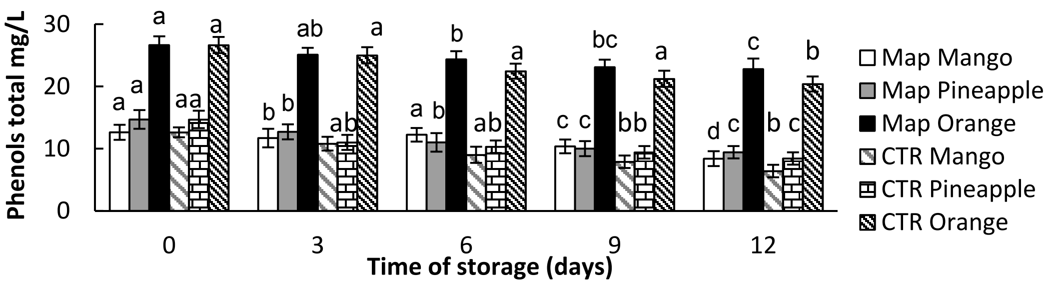

Figure 1: Total phenolics content (f.w mg/L) of mango, pineapple and orange when stored for 0, 3, 6, 9 and 12 days at 10°C. Single error bar for each treatment per fruit.

Table 2: Sensory analysis applied to fresh-cut mix fruit of mango, pineapple and orange during 12 days at 10°C and 90% RH

Day of storage			Appearanc	Juiciness	Flavor	Texture	Odor	Overall liking
Mango	0	MAP	8.4±0.6	7.5±0.9	8.8±0.7	8.0±0.3	7.91±0.8	8.5±0.2
		CTR	8.4±0.6	7.5±0.9	8.8±0.7	8.0±0.3	7.91±0.8	8.5±0.2
	3	MAP	7.5±0.4	7.0±0.5	8.6.±0.2	7.0±0.6	7.50±0.4	7.9±0.5
		CTR	7.6±0.3	7.3±0.4	8.4.±0.3	6.8±0.3	7.50±0.4	7.8±0.2
	6	MAP	6.3±0.1	6.2±0.4	7.8±0.5	6.0±0.4	6.2±0.6	6.7±0.4
		CTR	5.9±0.7	5.5±0.3	7.1±0.7	5.3±0.4	5.4±0.5	5.7±0.4
	9	MAP	5.9±.0.3	5.8±0.2	6.9±0.7	6.1±0.5	6.0±0.3	6.6±0.2
		CTR	5.0±0.2	5.0±0.1	7.0±0.5	5.2±0.4	4.9±0.8	5.7±0.3
	12	MAP	5.1±0.5	5.3±0.6	6.2±0.4	5.7±0.3	5.9±0.1	6.0±0.6
		CTR	4.0±0.2	4.3±0.4	4.5±0.5	4.1±0.5	3.8±0.8	4.3±0.5
Pineapple	0	MAP	8.7±0.3	8.1.±0.4	7.9±0.4	8.5±0.4	7.3±0.6	8.7±0.6
		CTR	8.7±0.3	8.1.±0.4	7.9±0.4	8.5±0.4	7.3±0.6	8.7±0.6
	3	MAP	8.3±0.2	8.1±0.5	7.8±0.6	8.7±0.2	7.3±0.3	8.1±0.3
		CTR	8.0±0.6	8.5±0.4	7.5±0.3	8.5±0.4	7.1±0.5	7.8±0.5
	6	MAP	8.1±0.4	7.0±0.5	8.0±0.6	8.1±0.1	7.8±0.7	7.7±0.3
		CTR	7.3±0.2	6.7±0.4	7.0±0.2	7.7±0.4	7.0±0.2	7.4±0.6
	9	MAP	7.5±0.2	6.3±0.7	7.1±0.5	7.6±0.3	7.4±0.3	7.0±0.4
		CTR	6.2±0.1	5.9±0.2	6.2±0.3	5.3±0.3	5.0±0.1	5.5±0.3
	12	MAP	6.6±0.4	6.0±0.4	6.7±0.2	6.4±0.1	6.7±0.5	6.5±0.2
		CTR	5.3±0.5	5.1±0.1	5.3±0.0	4.6±0.4	3.5±0.2	5.0±0.5
Orange	0	MAP	8.5±0.2	8.6±0.4	8.5±0.1	8.5±0.2	8.2±0.3	8.5±0.1
		CTR	8.5±0.2	8.6±0.4	8.5±0.1	8.5±0.2	8.2±0.3	8.5±0.3
	3	MAP	8.3±0.4	8.7±0.3	8.8±0.1	8.1±0.4	8.0±0.4	8.5±0.3
		CTR	8.0±0.4	7.9±0.2	8.1±0.4	7.5±0.5	7.5±.0.7	8.0±0.4
	6	MAP	7.8±0.3	7.0±0.5	7.0±0.4	7.1±0.5	7.3±0.3	7.2±0.2
		CTR	7.0±0.3	6.4±0.3	6.0±0.0	6.8±0.0	6.7±0.0	6.7±0.4
	9	MAP	7.3±0.5	7.0±0.0	6.0±0.0	7.5±0.3	6.8±0.1	7.0±0.5
		CTR	6.5±0.0	6.1±0.0	5.9±0.4	6.1±0.0	6.2±0.0	6.4±0.3
	12	MAP	6.0±0.3	6.0±0.4	6.0±0.2	7.0±0.4	6.5±0.6	6.7±0.5
		CTR	5.8±0.4	5.4±0.2	4.8±0.4	5.1±0.1	5.3±0.0	5.3±0.4

Different letters within the same landrace indicate values statistically different (P ≤ 0.05, according to Tukey's test). (Data are means ± SE; n =9).

4. Conclusions

The gas mixture treatment with 70% N_2, 10% O_2, 20% CO_2, proved to be the effective MAP system in extending the shelf life of the mixed fruits maintaining good color characteristics, texture, odor and juiciness during 9 days of storage at 10 °C. Moreover, MAP lowered weight loss and decay development without noticeable loss in quality attributes and without relevant changes in total sugars, antioxidant activity and phenolic total content contents. This treatment maintained the sensory quality of the fresh-cut mixed fruit (compared with CTR) and it inhibited the growth of spoilage microorganisms. MAP, in combination with refrigeration, had beneficial effects on the inhibition of enzymatic browning. In conclusion, MAP slows the natural deterioration of a product, but there is no enhancement of the product quality. Nevertheless, with a good initial product, the quality characteristics of fresh fruit may be prolonged. Map technique can be commercially implemented and it may encourage a greater consumption of fresh prepared fruits.

Reference

Allegra A., Barone, E., Inglese, P., Todaro, A., Sortino, G., 2015a, Variability of sensory profile and quality characteristics for ‘Pesca di Bivona’and ‘Pesca di Leonforte’peach (*Prunus persica* Batsch) fresh-cut slices during storage, Postharvest Biology and Technology, 110, 61-69, DOI:10.1016/j.postharvbio.2015.07.020.

Allegra A., Inglese, P., Sortino, G., Settanni, L., Todaro, A. Liguori, G., 2016, The influence of *Opuntia ficus-indica* mucilage edible coating on the quality of “Hayward” kiwifruit slices, Postharvest Biology and Technology, 120, 45-51. DOI:10.1016/j.postharvbio.2016.05.011

Allegra A., Sortino G., Miciletta G., Riotto M., Fasciana T., Inglese P., 2015b, The Influence of Harvest Period and Fruit Ripeness at Harvest on Minimally Processed Cactus Pears (*Opuntia Ficus-Indica* L. Mill.), Stored Under Passive Atmosphere. Postharvest Biology and Technology 104, 57–62.

Brand-Williams W, Cuvelier ME, Berset C., 1995, Use of a free radical method to evaluate antioxidant activity. LWT - Food Science and Technology, (1):25–30. DOI:10.1016/s0023-6438(95)80008-5

Cocozza F.M., Jorge J.T., Alve R.E., Filigveeiras H.A.C., Pereira M.E.C., 2004, Respiration rate and chemical characteristics of cold stored “Tommy Atkins’ mangoes influenced by 1-MCP and modified atmosphere packaging*,* Acta Horticulturae, 645, 645-650. DOI:10.17660/actahortic.2004.645.85.

Farina V., Gianguzzi G., Mazzaglia A., 2016, Fruit quality evaluation of affirmed and local loquat (*Eriobotrya japonica* Lindl) cultivars using instrumental and sensory analyses, Fruits, 71, 105-113.

González-Aguilar G.A., Ruiz-Cruz S., Cruz-Valenzuela R., Rodrıguez-Félix A., Wang C.Y., 2004, Physiological and quality changes of fresh-cut pineapple treated with antibrowning agents, LWT, 37,369-376.

Ingrassia M., Sgroi F., Tudisca S., Chironi S., 2016, Study of Consumer Preferences in Regard to the Blonde Orange cv. *Washington Navel* “Arancia Di Ribera PDO”, Journal of Food Products Marketing, 1-18.

Liguori G, Farina V, Sortino G, Mazzaglia A, Inglese P., 2014, Effects of 1-methylcyclopropene on postharvest quality of white- and yellow-flesh loquat (*Eriobotrya japonica* Lindl.) fruit, Fruits, 69(5), 363–70.

Liguori G., D’Aquino S., Sortino G., De Pasquale C., Inglese P., 2015, Effects of passive and active modified atmosphere packaging conditions on quality parameters of minimally processed table grapes during cold storage, Journal Berry Research, 5(3), 131–143. DOI:10.3233/jbr-150101.

Liguori G., Sortino G., Gentile C., Gianguzzi G., Saletta F., D’Asaro A., Inglese P. Farina V., 2017**,** Quality changes in fresh-cut mango cubes submitted to different gas partial pressure of active MAPs. ISHS VIII International Postharvest Symposium: Enhancing Supply Chain and Consumer Benefits, Acta Horticulturae, In press.

Marrero A., Kader A. A., 2006, Optimal temperature and modified atmosphere for keeping quality of fresh-cut pineapples, Postharvest Biology and Technology 39(2) 163-168.

Montero-Calderón M Rojas-Graü MA, Martín-Belloso O., 2009, Mechanical and chemical properties of Gold cultivar pineapple flesh (*Ananas comosus*). European Food Research Technology, 230(4), 675–86.

Oms-Oliu G., Rojas-Graü, M. A., González, L. A., Varela, P., Soliva-Fortuny, R., Hernando, M. I. H., Martín-Belloso, O., 2010, Recent approaches using chemical treatments to preserve quality of fresh-cut fruit: A review. Postharvest Biology and Technology, 57(3), 139-148.

Padmanabhan M., Prince P.S.M., 2012, S-allylcysteine ameliorates isoproterenol-induced cardiac toxicity in rats by stabilizing cardiac mitochondrial and lysosomal enzymes, Life Sci., 80, 972–978.

Po L.O., Po E.C., 2012, Tropical Fruit : Banana, Mango, and Pineapple, Handbook of Fruits and Fruit Processing, Wiley-Blackwell; 565–89. DOI:10.1002/9781118352533.ch32.

Sortino G., Allegra A., Inglese P., Chironi S. Ingrassia, M., 2016, Influence of an evoked pleasant consumption context on consumers' hedonic evaluation for minimally processed cactus pear (*Opuntia ficus-indica*) fruit. Acta Horticulturae, 1141, 327-334, DOI:10.17660/ActaHortic.2016.1141.41.

Sortino G., Ingrassia, M., Allegra, A. and Inglese, P. 2015. Sensory evaluation and suitability for fresh-cut produce of white peach [*Prunus persica* (L.) Batsch] 'Settembrina di Bivona', Acta Horticulturae, 1084,787-790. DOI: 10.17660/ActaHortic.2015.1084.107.