Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1679-9275
ISSN on-line: 1807-8621
Doi: 10.4025/actasciagron.v36i2.17192

Influence of waxing coupled to 1-methylcyclopropene on compositional changes in early harvested 'gold' pineapple for export

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ABSTRACT. This work evaluated the changes in quality in early-harvested 'Gold' pineapple after coating with wax and exposure to 1-Methylcycloprepene before or after coating. The storage conditions and the experimental period simulated those of shipping and marketing, assuming that Ceará, Brazil, is the production site and Europe is the marketplace. Evaluation was performed after harvest, upon removal of the fruit from cold storage, and every three days during room storage. Evaluations included visual quality of the fruit, shell yellowing, mass loss, flesh color, soluble solids, titratable acidity, pH, soluble solids to acid ratio, ascorbic acid, total soluble sugars, reducing sugar, phenolic content, and yellow flavonoids. Low temperature was the key variable for maintaining fruit quality during storage and simulated shipping. Waxing had a remarkable effect on visual quality, delaying yellowing and reducing shell dehydration. Those effects were not enhanced by the application of 1-MCP. 1-MCP treatment resulted in the maintenance of total phenolic content and retention of yellow flavonoids. Fruit flesh became lighter, while yellow color became more vivid during storage. Sugars and pH varied little during storage, while the decline in TA was more intense in waxed fruit. 1-MCP and waxing may be combined to preserve external and internal quality.

Keywords: *Ananas comosus* L. Merrill, shipping, market, shell appearance, eating quality.

Influencia de revestimento associado ao 1-metilciclopropeno nas alterações do abacaxi 'Gold' colhido verdoso para exportação

RESUMO. Este trabalho objetivou determinar as mudanças na qualidade do abacaxi 'Gold' colhido verdoso, recoberto com cera e exposto ao 1-MCP antes ou após o recobrimento. As condições de armazenamento simularam o transporte e comercialização, considerando o estado do Ceará como o centro de produção e Europa como o centro de comercialização. As avaliações ocorreram após a aplicação dos tratamentos, após a retirada da refrigeração e a cada três dias durante o armazenamento ambiente e incluiu qualidade visual, perda de massa, amarelecimento da casca, coloração da polpa, sólidos solúveis, acidez titulável, pH, relação sólidos solúveis e acidez, açúcares solúveis, açúcares redutores, ácido ascórbico, flavonóides amarelos e compostos fenólicos totais. A refrigeração foi a chave para a conservação da qualidade durante o transporte. O recobrimento com cera conservou a qualidade visual reduzindo a desidratação e atrasando o amarelecimento da casca. Tratamento com 1-MCP não incrementou estes efeitos, mas resultou na conservação dos teores de flavonóides amarelos e fenólicos. A polpa tornou-se clara e vívida durante o armazenamento. Açúcares e pH variaram pouco durante o armazenamento, enquanto a acidez titulável dos frutos recobertos declinou mais intensamente. Cera e 1-MCP podem ser combinados para a preservação da qualidade visual e interna de abacaxi 'Gold'.

Palavras-chave: *Ananas comosus* L. Merrill, transporte, comercialização, aparência da casca, qualidade comestível.

Introduction

Pineapple (*Ananas comosus* L. Merrill) is a highly appreciated fruit throughout the world and is produced mostly in tropical areas, including Brazil (KIST et al., 2011). Despite the high production in Brazil, exports are low compared to those of Costa Rica and Thailand.

'Gold' cultivar (MD2) has been prominent in the international market because of its sensory characteristics, in particular, its flavor, sweetness to acidity balance, and juiciness (MONTERO-CALDERÓN, et al., 2010). This cultivar has been planted in Ceará state as an alternative to the local varieties and for export. Despite being a non-climacteric fruit, with eating quality determined at the time of harvest, compositional changes take place during storage; shell yellowing, dehydration, and loss of ascorbic acid impoverish the appearance and nutritional quality of the 'Gold' pineapple during storage and/or commercialization (MACHADO et al., 2009). Ethylene can greatly affect the quality of harvested products. These effects can be beneficial or deleterious depending on the variety and its ripening stage. 1-MCP (1-methylcyclopropene), an ethylene antagonist, interacts with ethylene receptors and prevents ethylene-dependent responses (SISLER; SEREK, 2003). It has been commercially used to extend the shelf-life of apples (WATKINS, 2006). Studies have shown that 1-MCP maintains the intrinsic levels of components such as phenolics (FAWBUSH et al., 2009) and flavonoids (MacLEAN et al., 2006). On the other hand, primary plant surfaces are impregnated with waxes produced by epidermal cells (JETTER; KUNST, 2008). These waxes serve as a protective barrier against water loss, UV light, pathogens and insects. The Carnauba palm (*Copernicia cerifera*) is among the most important plant sources for the commercial production of waxes (JETTER; KUNST, 2008). Carnauba´s wax is relatively rich in aliphatic esters, with varying overall chain lengths of both acyl and alkyl groups, and it contains characteristic admixtures of cinnamates and lactones (REGERT et al., 2005). Studies have shown that application of carnauaba-based wax emulsions helps to maintain visual quality of tangor (MACHADO et al., 2012). In our previous study we observed that carnauba-based wax lowered dehydration and reduced water loss in field-ripe pineapples (MACHADO et al., 2009).

This study examines the effects of coating with carnauba-based wax coupled with 1-MCP on the appearance and eating quality of early-harvested ‘Gold’ pineapple produced in Ceará State, Brazil and marketed in Europe.

Material and methods

‘Gold’ cultivar pineapples were harvested in the early morning from fields where fruit is grown for export in the Acaraú irrigation district, Acaraú County (Latitude: 3º07’13”S, Longitude: 40º05’13”W), Ceará state, transported to the packing house and sorted for size (average length 180 mm and average width 132 mm), shape (cylindrical), weight (average weight 1.980 g) and ripeness (fruit surface covered with up to 25% yellow color). After sorting, fruits were brushed, rinsed in chilled tap water, air-dried, forced-air cooled to 8ºC, and divided into four sets of 42 fruits each. The first set served as the control; the second set was briefly dipped (approximately 20 seconds) in carnauba-based wax, commercially available as Aruá Tropical®, and diluted with distilled water (1:1, v:v); the third set was dipped in carnauba-based wax and exposed to 500 $\mu L\ L^{-1}$ 1-MCP; and the fourth set was exposed to 500 $\mu L\ L^{-1}$ 1-MCP and then dipped in wax.

Fruit that was exposed to gaseous 1-MCP was stored at 8 ± 1ºC (90 ± 5% RH) for 12 hours. The gaseous 1-MCP was generated by mixing SmartFresh powder (0.14% active ingredient, AgroFresh–Hohm and Haas Company) with deionized water in a portable chamber, which was assembled in a cold room of the packing house. Small, portable fans were placed inside the chamber to ensure that the 1-MCP gas was evenly diffused around the pineapples. Following these treatments, the fruit was transported by truck in a refrigerated container (8 ± 2ºC) to the Laboratory of Postharvest Physiology and Technology of the Embrapa, located in Fortaleza, Ceará State, and stored for 13 days at 8 ± 1ºC, 85 ± 5% R.H. (shipping simulation). The fruit was then stored at room temperature, 22 ± 2ºC, 85 ± 5% R.H. (marketing simulation) for 12 days.

Evaluation of the fruit’s visual quality, mass loss, development of the shell’s yellow color, internal color, soluble solids, titratable acidity, pH, vitamin C content, total soluble sugars and reducing sugars, total phenolic content, and yellow flavonoid content were conducted immediately after the arrival of fruit at Embrapa´s facilities. The fruit was also evaluated when it was transferred from the cold room to ambient temperature condition, and then every three days until the end of storage.

Visual quality was determined based on the following scale: 5, excellent: freshly harvested with turgid and shining eyes; 4, good: fresh with shining eyes showing slight desiccation; 3, fair (limit of salability): eyes presenting visible desiccation with small darkened areas and free of disease; 2, poor: eyes presenting severe desiccation with darkened areas up to 25% and free of disease; 1, inappropriate: eyes presenting intense desiccation with darkened surface areas up to 50%, juice leakage, and/or apparent signs of disease. Shell yellowing was evaluated using the following scale: eyes showing yellow surface area up to 25%; eyes showing yellow surface area up to 50%; eyes showing yellow surface area up to 75%; eyes with yellow surface area above 90%. Visual quality and shell yellowing data were the average of the determinations performed by three trained judges.

The mass loss was determined by weighing each fruit individually during storage and then calculating the mass loss in relation to fruit mass at harvest. The results were expressed as percentages (%).

Flesh color was determined using a Minolta Chroma Meter (Minolta Corporation Instrument Systems) calibrated to a white porcelain reference plate. Brightness, chromaticity, and hue angle values were scored from the flesh of longitudinal halves. The contents of soluble solids were determined in juice samples taken from the pineapple longitudinal halves with a digital refractometer (0 – 45°Brix) (Palette 100, Atago, Co., Ltd) and expressed as degree Brix. Acidity was determined by titration with 0.1 N NaOH with an end point of pH = 8.2 and was expressed as mg of citric acid 100 g^{-1} of fresh weight (fw); pH was measured with a pH meter directly from the juice.

The ascorbic acid content was measured according to the methodology reported by Hernádez et al. (2006) and expressed as mg 100 g^{-1} fw. Total soluble sugar and reducing sugar (RS) were determined following the methodology reported by Yemn and Willis (1954) and Miller (1959), respectively and expressed as mg 100^{-1} g fw. The yellow flavonoid levels were determined according to the methodology described by Francis (1982) and expressed as mg 100^{-1} g fw, while total phenolic content was determined using the methodology of Larrauri et al. (1997) with the Folin-Ciocalteu reagent and gallic acid as the standard. The results are expressed as gallic acid equivalents (GAE).

The assay was conducted using an entirely randomized model in a split plot arrangement. The main plot was composed of the treatments (control, wax-coating, exposure to 1-MCP prior to wax-coating and exposure to 1-MCP after wax-coating), while the subplots included six storage periods (0, 13, 16, 19, 22 and 25 storage days). All of the data were subjected to analysis of variance (SISVAR 4.3) (FERREIRA, 2011). Linear regressions were used to describe the trends during storage ($R^2 \geq 70\%$), according to the procedure available in SAS. Tukey´s test ($p \leq 0.05$) was used to compare treatments classification when the F values were significant for the main effects, and the Kruskal and Wallis test was used for comparisons among treatments for visual quality. The data are expressed as the average of 10 replications, with each fruit equal to 1 replication, for the evaluation of visual quality, mass loss, and shell yellowing, while seven replications were used for the remaining evaluated variables.

Results and discussion

Coating 'Gold' pineapple with carnauba-based wax reduced the loss of visual quality during cold and room temperature storage (Table 1). At the end of cold storage, 50% of the wax-coated pineapples presented visual quality similar to that observed at harvest. Exposure of fruits to 1-MCP did not enhance the benefits achieved by coating. Just three days after transferring the fruit from cold to room temperature storage, the visual quality of the control fruit was rated as 'fair', mostly due to shell dryness, and had reached the limit for salability, whereas 50% of wax-coated fruits presented quality similar to that observed at harvest. After 6 days in room temperature storage the control fruit was no longer marketable because 80% of the fruit exhibited poor quality. At that time, all of the coated pineapples were marketable, with a visual quality rating of 'fair'. After 9 days of room temperature storage, all untreated pineapples had inappropriate visual quality, while 20% of the coated ones remained marketable. Thereafter, the pineapples were no longer marketable, regardless of treatment. Wax has been used to preserve maximal fruit quality during storage by reducing peel dehydration, maintaining color intensity and adding gloss to the peel (MACHADO et al., 2012).

Table 1. Appearance of 'Gold' pineapple as percentage of samples within each treatment, classified as excellent (E), good (G), fair (F), poor (P), and inappropriate (I) by the Kruskal and Wallis test, at 5% probability, after treatment with 1-MCP applied prior to or after waxing and stored for 25 days (13 days at 8 ± 1°C, 90 ± 5% RH (CS), plus 12 days at 22 ± 1°C, 90 ± 5% RH (RS)).

Treatment	Visual quality of the samples (%)														
	Harvest		13 (CS)				3 (RS)			6 (RS)			9 (RS)	
	E	G	E	G	F	P	F	P	I	F	P	I	P	I
Control	40	60			100			80	20			100		100
Wax	50	50	50	40	10		100			20	80		40	60
Wax+1-MCP	40	60		70	30		70	30		20	80		10	90
1-MCP+Wax	40	60		30	40	30	60	40		30	70		10	90

Changes in shell color were dependent on temperature because shell yellowing was a great deal more intense after transferring the fruit from cold to room storage (Figure 1).

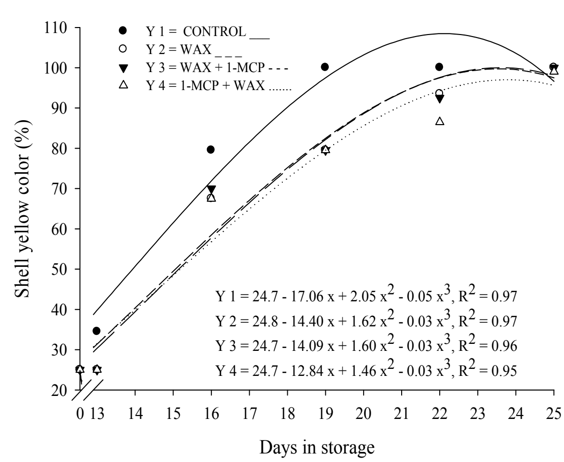

Figure 1. Shell yellowing (%) of 'Gold' pineapple treated with 1-MCP applied prior to or after waxing and stored for 25 days (13 days at 8 ± 1°C, 90 ± 5% RH, plus 12 days at 22 ± 1°C, 90 ± 5% RH).

The application of wax delayed shell yellowing during cold and room temperature storage, and the effect was greater during room temperature storage. After 3 days under room temperature conditions, the untreated fruits were just over 10% yellower than the treated ones, regardless of treatment. Thereafter, a synergistic effect was observed between waxing and exposure to 1-MCP prior to waxing, as fruit treated with wax and 1-MCP exhibited the greatest percentage in green color. After 9 days of room storage, the untreated fruits were mostly yellow, while the treated ones still exhibited shades of green, especially those exposed to 1-MCP before coating.

Loss of shell green color is associated with the natural ripening process triggered by ethylene and occurs as the result of the breakdown of chlorophyll molecules, which occur in parallel with an increase in carotenoid content (RODRIGO; ZACARIAS, 2007). Therefore, both the application of wax alone and the application of wax after exposure to 1-MCP, delayed the natural metabolic process that culminates in shell yellowing. 1-MCP is believed to inhibit the action of ethylene by binding irreversibly to the ethylene receptor (BLANKENSHIP; DOLE, 2003), and the presence of 1-MCP bound to any member of the ethylene receptor protein family (e.g., ETR1 or ERS1) should result in the inhibition of all downstream transcription factors that are up-regulated by ethylene. Green color retention also has been observed in 'Tahiti' limes treated with wax or 1-MCP. No synergistic effect was observed, however, when 1-MCP was applied prior to waxing (JOMORI et al., 2003).

The loss of mass from treated fruit did not differ from that of the control fruit ($p < 0.05$) but increased linearly with storage time ($Y = -0.662 + 0.41(x)$, $R^2 = 0.96$). At the end of room storage, loss of mass reached approximately 10% of the initial value. This result disagrees with a previous study by Machado et al. (2009), in which application of carnauba-based wax reduced the mass loss of field-ripe 'Gold' pineapple. Surface coatings block pores in the skin, which reduces permeability to water vapor and gases and may reduce water loss. The discrepancy among results reporting on the same variety of pineapple under the same storage conditions, however, suggests that the intensity and/or permanence of the effect of waxing depends on fruit hydration status, which is governed by fruit maturity.

Pineapple flesh turned a little lighter at the end of cold storage, as the brightness average values increased slightly. No significant difference, however, was observed between harvest and the end of cold storage (Table 2). A decrease in brightness was observed only after 9 days under room temperature conditions. This decrease, however, was not high enough to cause darkening of the tissue. Thereafter, the brightness values increased slightly. The flesh's yellow color, as measured by the angle hue, averaged 95.13 at harvest and became yellower, as the hue angle decreased to 94.00 at the end of cold storage. The yellow color remained fairly stable during room storage (Table 2). The patterns of change in the chroma values indicated that the flesh color became more vivid; the chroma values rose from 36.34 at harvest to 40.4 when transferring from cold to room storage and then rose to 42.2 by the end of the experimental period. These high chroma values indicate that the color of the 'Gold' pineapple flesh is more pigmented than that of the 'Smooth Cayenne' and resembles that of Premium select when it is harvested at commercial maturity (MARRERO; KADER, 2006).

Table 2. Brightness, hue angle, and chromaticity of 'Gold' pineapple treated with 1-MCP applied prior to or after waxing and stored for 25 days (13 days at 8 ± 1°C, 90 ± 5% RH (CS), plus 12 days at 22 ± 1°C, 90 ± 5% RH (RS)).

Treatments	Storage time (days)[(1)]					
	Harvest	13 (CS)	3 (RS)	6 (RS)	9 (RS)	12 (RS)
			Brightness			
Control	71.74 a	73.04 a	73.47 ab	70.29 a	70.60 a	70.90 a
Wax	71.18 a	72.93 a	70.00 a	73.01 a	71.80 a	72.99 ab
Wax+1-MCP	71.98 a	71.82 a	73.08 ab	70.55 a	71.92 a	74.48 ab
1-MCP+Wax	72.05 a	73.68 a	74.16 b	71.39 a	68.29 a	76.03 b
			Hue angle			
Control	95.47 a	93.58 a	94.18 a	94.05 b	92.91 a	93.81 b
Wax	94.35 a	93.82 a	93.48 a	92.56 a	92.59 a	92.50 a
Wax+1-MCP	95.36 a	94.57 a	94.25 a	92.43 a	93.55 a	93.42 ab
1-MCP+Wax	95.33 a	94.04 a	93.04 a	93.86 b	92.81 a	94.06 b
			Chromaticity			
Control	35.37 a	41.55 a	39.72 ab	37.63 a	43.61 b	42.44 a
Wax	38.05 a	40.36 a	37.26 a	40.96 b	41.40 ab	43.51 a
Wax+1-MCP	35.34 a	38.69 a	40.43 b	41.38 b	40.22 a	41.40 a
1-MCP+Wax	36.61 a	40.93 a	41.65 b	40.84 b	40.59 ab	41.58 a

[(1)]Means followed by equal letters, in the columns, do not differ by Tukey's test, at 5% probability.

The content of soluble solids was not influenced by the treatments or length of storage ($p < 0.05$). The level of soluble solids measured at harvest averaged 15.3°Brix, which was maintained during cold storage but decreased slightly to 14.9 during room storage. No significant differences were observed among treatments.

The titratable acidity increased at the end of cold storage and then decreased during room storage for all treatments (Figure 2). Coating the pineapples with wax seemed to reduce the acidity levels, suggesting that organic acids are substrates for the respiration process. The decline, however, was less intense in fruits exposed to 1-MCP, especially if they were exposed prior to coating. The effect of 1-MCP on the retention of organic acids in guava, which indicates a delay in fruit ripening, was reported by Bassetto et al. (2005).

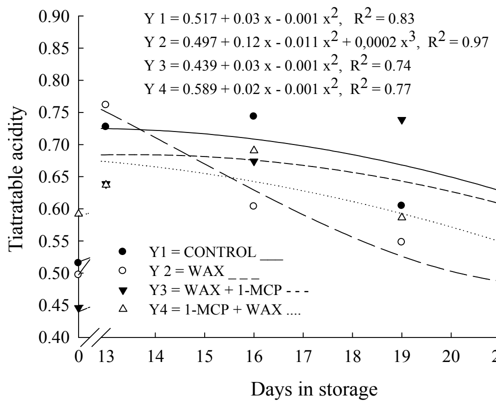

Figure 2. Titratable acidity (mg of citric acid 100^{-1} g fw) of 'Gold' pineapple treated with 1-MCP applied prior to or after waxing and stored in air for 25 days (13 days at 8 ± 1°C, 90 ± 5% RH, plus 12 days at 22 ± 1°C, 90 ± 5% RH).

Contrary to the trends observed for TA, pH values increased during storage ($Y = 3.58 – 0.051x + 0.004x^2 - 00008x^3$, $R^2 = 0.82$) and averaged 3.55, 3.56, 3.64, and 3.68 for pineapples that were untreated, coated, exposed to 1-MCP after coating and exposed to 1-MCP prior to coating, respectively, with no significance difference among treatments (Tukey´s test at 5% probability).

The pattern of changes in SS to TA ratio were opposite to those observed in TA, given that SS content was not affected by application of the treatments and SS remained fairly stable during storage (Figure 3).

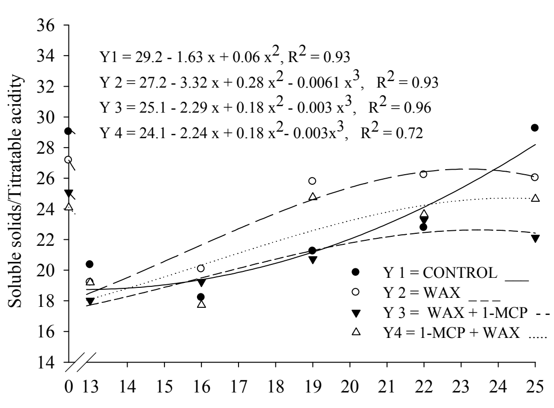

Figure 3. Soluble solids/Titratable acidity of 'Gold' pineapple treated with 1-MCP applied prior to or after waxing and stored for 25 days (13 days at 8 ± 1°C, 90 ± 5% RH, plus 12 days at 22 ± 1°C, 90 ± 5% RH).

The control fruit had the lowest SS to TA ratio after transferring from cold to room storage and up to the sixth day in room storage. Commercially, the SS to TA ratio is regarded as the most reliable measure of fruit flavor (SARADHULDHART; PAULL, 2007).

The sweetness index, the SS to TA ratio, observed for 'Gold' pineapple grown under local conditions was higher than those reported by Montero-Calderón et al. (2010) for ripe 'Gold' pineapple grown in Costa Rica. Thus, early 'Gold' pineapple harvested for export in Ceará state is desirable for consumption.

Total soluble sugars averaged 11.30 mg 100 g^{-1} fw and followed a similar pattern as that presented by soluble solid content, decreasing just slightly from 11.65 mg 100 g^{-1} fw at harvest to 11.35 mg 100 g^{-1} fw at the end of storage, reinforcing the previously observed correlation between these variables.

Reducing sugars averaged 3.52 mg 100 g^{-1} fw and decreased from 3.71 mg 100 g^{-1} fw at harvest to 2.74 mg 100 g^{-1} fw at the end of storage. A previous study by Machado et al. (2009) indicates higher amounts of SS, TSS, and RS (16.3°Brix, 16.27 mg 100 g^{-1} fw, and 6.0 mg 100 g^{-1} fw, respectively, at harvest) in field-ripened 'Gold' pineapple. Despite being harvested early, the TSS content found in this study was higher than that reported by Souto et al. (2004) for 'Pérola' pineapple (12.86 mg 100 g^{-1} fw) harvested at commercial maturity.

Storage temperature played a major role in the maintenance of Vitamin C because losses were higher under room temperature conditions than in cold storage (Table 3). 1-MCP treated pineapples showed the highest levels of ascorbic acid at harvest. This effect, however, did not persist over the course of storage because no significant differences were observed among treatments over the course of storage ($p < 0.05$). Application of 1-MCP has been associated with lower ascorbic acid levels during the storage of 'Perola' pineapples (DANTAS JÚNIOR et al., 2009).

Table 3. Vitamin C (mg ascorbic acid 100^{-1} g fw) of 'Gold' pineapple after treatment with 1-MCP applied prior to or after waxing and stored for 25 days (13 days at 8 ± 1°C, 90 ± 5% RH (CS), plus 12 days at 22 ± 1°C, 90 ± 5% RH(RS)).

Treatments	Storage time (days)[(1)]					
	Harvest	13 (CS)	3 (RS)	6 (RS)	9 (RS)	12 (RS)
	Vitamin C (mg ascorbic acid/100 g fw)					
Control	45.78^a	47.11^a	40.25^b	31.70^a	36.23^a	30.37^a
Wax	41.84^a	50.65^a	33.56^a	34.70^a	35.86^a	32.09^a
Wax+1-MCP	64.09^b	51.66^a	33.19^a	32.23^a	37.00^a	34.71^a
1-MCP+Wax	64.58^b	50.90^a	35.33^a	31.39^a	34.57^a	32.45^a

[(1)]Means followed by equal letters, in the columns, do not differ by Tukey's test, at 5% probability.

The total phenolic content increased under cold storage for all treatments, with untreated fruits showing the highest levels, and then declined at the end of cold storage (Figure 4). Loss of phenolic content was much lower in coated fruits; the slope of the decline with time was also smaller than that of the control fruit. Comparing the control, coated fruits and treatment with 1-MCP, application of 1-MCP, especially when applied prior to waxing, was effective at maintaining the intrinsic levels of total phenolics.

Fawbush et al. (2009) reported that the application of 1-MCP on 'Empire' apples stored in air at 0.5ºC resulted in a higher amount of total phenolic content in the peel compared to untreated fruits. A decline in the levels of total phenolic compounds during room storage might have occurred as the result of these compounds being irreversibly bound to polymeric matrices, such as proteins, to form larger compounds. Overall, the total phenolic values observed in this study are lower than 94 mg GAE 100 g^{-1} fw, which was the value reported by Fu et al. (2011) for pineapple.

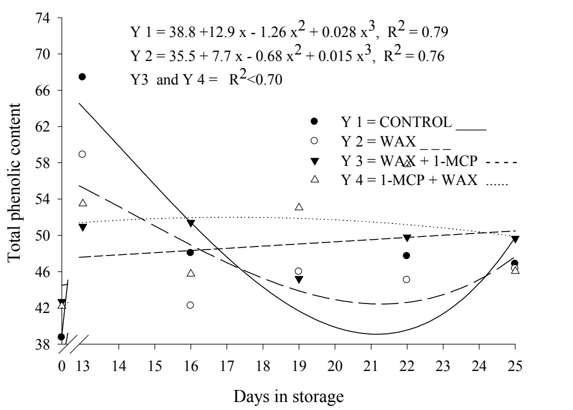

Figure 4. Phenolic content (mg 100^{-1} g fw) of 'Gold' pineapple treated with 1-MCP applied prior to or after waxing and stored for 25 days (13 days at 8 ± 1ºC, 90 ± 5% RH, plus 12 days at 22 ± 1ºC, 90 ± 5% RH).

The content of yellow flavonoids declined from harvest to the end of cold storage. The decline, however, was less intense in treated fruits (Figure 5).

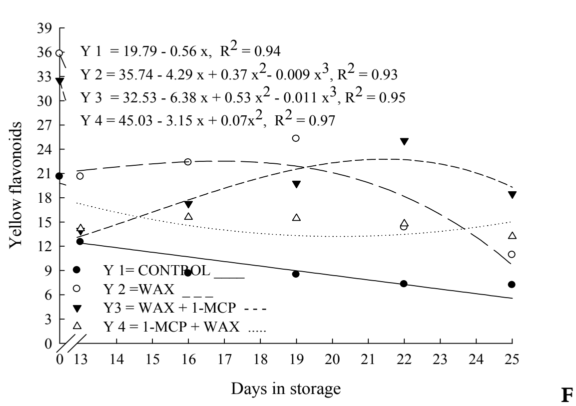

Figure 5. Yellow flavonoids levels (mg 100^{-1} g fw) of 'Gold' pineapple treated with 1-MCP applied prior to or after waxing and stored for 25 days (13 days at 8 ± 1ºC, 90 ± 5% RH, plus 12 days at 22 ± 1ºC, 90 ± 5% RH).

Application of 1-MCP coupled with waxing greatly influenced the yellow flavonoid contents because these fruits exhibited the greatest retention of yellow flavonoids when compared with untreated fruits. These results agree with those of MacLean et al. (2006), who found that exposure of 'Delicious' apples to 1-MCP resulted in greater retention of flavonoids, with the amount in treated fruit being 5% higher than that in the control fruit.

The decline in concentration of yellow flavonoids during cold storage and after transferring to room temperature conditions observed in this study may be attributable to the control fruit being subjected to higher levels of reactive oxygen species formed in response to the physiological stress of storage. Larrigaudière et al. (2004) reported that 'Blanquilla' pears treated with 1-MCP and cold-stored presented lower levels of cellular oxidative stress and an increase in the enzymatic antioxidant capacity of the tissue. Thus, the flavonoids might have been degraded through oxidation by reactive oxygen species. Alternatively, the decline might have occurred as the result of polymerization to form larger compounds.

Conclusion

Treatment of 1-MCP prior to waxing extends the visual and nutritional quality of early-harvested 'Gold' pineapple grown in Ceará State, Brazil to be marketed in Europe. The effects, however, are not synergistic.

Acknowledgements

We would like to acknowledge CNPq, for granting the scholarship to the first author, AgroFresh for the gift of SmartFresh, and Itaueira Agropecuária S.A. for supplying the pineapples.

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Received on May 5, 2012.
Accepted on September 14, 2012.