PERFORMANCE DURING POST-HARVEST STORAGE OF BANANA CV. 'PRATA', 'MAÇÃ' AND 'NANICA' EXPOSED TO PHYSICAL AND CHEMICAL TREATMENTS

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ABSTRACT: Banana is the most consumed fruit in the world and Brazil is the second largest producer. Despite its global position, Brazil has an average of 40% losses during the post-harvest period. So, this experiment aimed at evaluating the efficiency of post-harvest treatments to improve the storage of banana cultivars cv. 'Prata', 'Maçã' and 'Nanica'. The fruits were acquired at CEASA with green peel, and were submitted to six different treatments: T- immersion in drinking water for 3 minutes (control), H3 - hot water (50 °C for 3 minutes), H8 - hot water (50 °C for 8 minutes), HP - immersion in hypochlorite 0.2% for 3 minutes, OS - immersion in soybean oil 10% for 3 minutes, and OM - immersion in mineral oil 10% for 3 minutes. The fruits were stored at room temperature at about 21 °C for 14 days and evaluated in three periods (1, 7 and 14 days) comparing peel color, flesh/peel ratio, titratable acidity (TA), soluble solids (SS), SS/TA ratio, and pH. The fruits of cv. 'Prata' and 'Maçã' submitted to the treatments H3, H8 and HP ripened at the same time as the control for peel color, which showed increased soluble solids, flesh/peel ratio, acidity and a decrease in pH. On the other hand, the cv. 'Nanica' did not respond significantly different when compared to the applied treatments and the control. The fruits treated with OM and OS were kept green for a longer time for the cultivars 'Prata' and 'Nanica', but there were some changes on peel color due dark spots in 'Prata' banana and a softening aspect in 'Nanica', indicating some level of toxicity of these treatments. Fruits of the 'Maçã' cultivar continued green with the application of mineral oil, without toxicity symptoms. In conclusion, the treatments applied did not show any advantage for storage of these fruits.

KEYWORDS: post-harvest loss, ripening, *Musa* sp.

COMPORTAMENTO PÓS-COLHEITA DURANTE ARMAZENAMENTO DE BANANAS 'PRATA', 'MAÇÃ' E 'NANICA' SUBMETIDAS A TRATAMENTOS FÍSICOS E QUÍMICOS

RESUMO: A banana é a fruta mais consumida no mundo, e o Brasil é o segundo maior produtor mundial. Apesar de seu ranking mundial, apresenta níveis de até 40% de perdas no período pós--colheita. O objetivo deste trabalho foi avaliar a eficiência de produtos utilizados para tratamento pós-colheita que permitam ampliar o tempo de armazenamento de banana das cultivares Prata, Maçã e Nanica. Os frutos, com coloração da casca totalmente verde, foram submetidos a seis diferentes tratamentos: T - imersão em água potável por 3 minutos (testemunha); H3 - hidrotérmico (50 °C por 3 minutos); H8 - hidrotérmico (50 °C por 8 minutos); HP - imersão em hipoclorito a 0,2% por 3 minutos; OS - imersão em óleo de soja a 10% por 3 minutos, e OM - imersão em óleo mineral a 10% por 3 minutos. Esses foram armazenados à temperatura ambiente com média de 21 ºC durante 14 dias e avaliados em três períodos (1; 7 e 14 dias), em relação à coloração da casca, relação polpa/casca, acidez titulável (AT), sólidos solúveis (SS), relação SS/AT e pH. Os frutos das cultivares Prata e Maçã, submetidos aos tratamentos H3, H8 e HP, amadureceram juntamente com a testemunha, cujo parâmetro foi a coloração observada, a qual apresentou aumento dos sólidos solúveis, relação polpa/casca, acidez e redução do pH; entretanto, os da cultivar Nanica não apresentaram diferenças para os tratamentos aplicados em relação à testemunha. Os tratamentos OS e OM mantiveram os frutos verdes das cultivares Prata e Nanica por mais tempo, porém observaram-se alterações da casca, que apresentou manchas escuras na banana 'Prata' e aspecto amolecido para a banana 'Nanica', indicando toxidez desses tratamentos. Os frutos da cultivar Maçã permaneceram verdes com a aplicação de óleo mineral e sem toxidez. A aplicação dos tratamentos testados não foi vantajosa para o armazenamento dos frutos.

PALAVRAS-CHAVE: amadurecimento, *Musa* sp., perdas pós-colheita.

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INTRODUCTION

Banana, a plant species of the monocot genus *Musa*, is native to Southeast Asia, was one of the first fruit species cultivated by humans. Introduced by the Portuguese in Brazil, it is cultivated from North to South, totaling 508 thousand hectares of cultivated area in 2008, with a production exceeding 7 million tons, second only to India. In Brazil, the most widespread cultivars are of the AAB group 'Prata' subgroup (Prata, Pacovan, Prata-Anã), which are responsible for approximately 60% of national production, followed by the AAB group 'Maçã' subgroup and the group AAA subgroup Cavendish, which include the varieties Nanica, Nanicão and Grande-Naine (CONAB, 2008).

The stage of banana fruit ripening is marked by a large increase in respiratory rate and ethylene production, characterizing it as climacteric and making it highly perishable. Thus, it should be harvested before the rise of the respiratory rate (pre-climacteric) for best and extended conservation (TAIZ & ZEIGER, 2004; CHITARRA & CHITARRA, 2005; PINHEIRO et al., 2005).

Although Brazil is the second largest banana producer in the world, it is a small exporter, limited by a high domestic consumption and a lack of product quality control (BRACKMANN et al., 2005). Factors affecting product quality are more related to fruit appearance and distribution than to its internal characteristics (MATSUURA et al., 2004; CHITARRA & CHITARRA, 2005).

It is in the post-harvest period, which begins at the time of separation between the mother plant and the fruit, when most of the losses occur, reaching levels of up to 40%, with great not only at the economic level, but also of nutritional significance. According to SANCHES et al. (2004), the handling methods used in the farm, the fruit packing, and the transport to distribution centers all favor the increase of banana mechanical damage. Under controlled conditions of temperature and relative humidity, the metabolic reactions that lead to product deterioration can be avoided. However, in a study at São Paulo Distribution Center, FERREIRA NETO et al. (2006) found that only 24% of bananas sold were in refrigerated chambers and these were not working adequately.

Immediately after harvest, many treatments can be used, including application of chemical fungicides, growth regulators, waxes, hydrothermal, and others, seeking to improve the fruit quality for conservation and to extend its shelf life. Currently, the search for natural, environmentally clean and debris-free methods has been intensified to extend the storage period with increased product quality without affecting the environment, the farmer and consumer's health, and being of low-cost (JUNQUEIRA et al., 2003; SPONHOLZ et al., 2004).

Based on this context, this study aimed at evaluating the efficiency of hydrothermal treatment, hypochlorite application, and vegetable oil to increase the shelf life of banana fruits of the cultivars Prata, Nanica and Maçã stored under ambient conditions.

MATERIAL AND METHODS

Non-acclimatized bananas cv. 'Prata', 'Nanica' and 'Maçã' were acquired at the Cascavel Distribution Center (CEASA) at the first day after harvest. After being removed from the boxes, totally green fruits were selected, non-standard fruits were discarded (BOTREL et al., 20022), following the formation of thirty-six plots of random groups formed by a bouquet of three fruits each.

Bananas of each cultivar were subjected to six treatments by immersion of fruits in the following solutions:

T - (control) drinking water at room temperature for three minutes; H3 - chlorinated water at 50 °C for three minutes; H8 - drinking water at 50 °C for eight minutes; HP - sodium hypochlorite with 0.2% active chlorine for three minutes; OS - soybean oil at 10% for three minutes, and OM -

immersion in mineral oil at 10% for three minutes (SPONHOLZ, 2004; ERABADUPITIYA & COSTA, 2005).

After application of each treatment, fruits were air-dried and stored at room temperature at approximately 21 ºC and the samples analyzed at one, seven and fourteen days for the parameters of soluble solids, titratable acidity, pH (INSTITUTO ADOLFO LUTZ, 2005), and flesh/peel ratio (BOTREL et al., 2002). For daily analysis of peel color of the banana fruits, it was used the color scale with notes of one to seven according to the proposal of the National Program for the Modernization of Agriculture (HORTIBRASIL, 2009), described below: 1 - completely green, 2 - green with yellow lines, 3 - more green than yellow, 4 - more yellow than green, 5 - yellow with green tips, 6 - yellow, and 7 - yellow with brown spots.

It was used a completely randomized design in sub-subplots, with three banana cultivars as a plot, six post-harvest treatments as subplots, and three storage times as sub-subplots. It was carried out analysis of variance and comparison of means using the Tukey's test at 5% probability using the SISVAR software version 4.6.

RESULTS AND DISCUSSION

In relation to soluble solids of the cv. 'Prata' fruits at 7 and 14 days, there were differences between the treatments and at 14 days, fruits treated with soybean (SO) and mineral (OM) oils showed the lowest values, indicating that they showed no maturation (Table 1). Moreover, there was a progressive increase in soluble solid levels during storage in all treatments. In relation to 'Nanica' fruits, the treatments did not differ significantly for any of the times analyzed, indicating that none of the post-harvest treatments delayed the onset of maturation in relation to the control. In fruits of the 'Maçã' cultivar, it was observed at seven days of storage that all treatments, except for the hydrothermal treatment for 8 minutes, showed low soluble solids. However, only fruits treated with soybean and mineral oil presented lower contents at 14 days, indicating that they were ripen (Table 1). According to CHITARRA & CHITARRA (2005), the final ripening stage, known as maturation, is characterized by changes in color and flavor when the fruit becomes suitable for consumption. In this study, although the fruits were in the ripening phase, the treatments impaired maturation, leading to loss of edible quality of the fruit.

TABLE 1. Soluble solid means (expressed in ° Brix) of banana fruits undergoing postharvest treatments and stored for 14 days.

Treat.	'Prata'			'Nanica'			'Maça'		
	Storage Period (days)			Storage Period (days)			Storage Period (days)		
	01	07	14	01	07	14	01	07	14
T	6.3a	15.0bc	24.5a	10.0a	15.0a	15.0a	7.8a	12.3ab	11.3bc
H3	7.3a	13.7bc	23.0a	11.3a	15.0a	17.5a	6.3a	7.8b	11.3bc
H8	7.5a	20.0ab	23.5a	12.5a	17.8a	17.5a	6.5a	18.0a	17.5ab
HP	7.3a	22.5a	24.8a	12.5a	17.5a	17.5a	5.0a	11.0b	22.3a
OS	7.3a	13.8cb	9.8b	8.0a	15.0a	12.3a	5.0a	6.0b	6.0c
OM	7.5a	12.5c	10.0b	12.3a	16.3a	15.0a	7.8a	7.5b	10.0c

Means, for each cultivar analyzed, followed by distinct lower-case letters in the columns differ statistically by the Tukey's test ($p<0.05$). T - Control, H3 - water at 50 °C for three minutes; H8 - water at 50 °C for eight minutes; HP - sodium hypochlorite for three minutes; OS - soybean oil for three minutes, and OM - mineral oil for three minutes.

All values are consistent with those found in the literature for bananas cultivars, which are between 0.9 and 26.60 °Brix, at the different ripening stages of the fruit (MANOEL, 2005; CHITARRA & CHITARRA, 2005; SILVA et al., 2006). However, the treatments used induced a great variation of soluble solids when compared to the results obtained by CERQUEIRA et al. (2000) and MATSUURA et al. (2004), which used 'Nanica' banana and resulted in averages

between 22.9% and 28.3%, while the results of the present experiment ranged from 8% to 17.75% on average, and it may indicate that the fruit did not complete their maturation within the evaluation time, since they were not air conditioned. JUNQUEIRA et al. (2004), working with non-conditioned fruits, found that treatments containing soybean oil controlled fruit ripening well in comparison to the control, finding values of solid contents in the fruits between 13.5 and 8.25% after 15 days of storage, which are lower than those observed in untreated fruits.

It can be seen in relation to fruit acidity of the 'Prata' cultivar (Table 2) significant differences only for seven days of storage, with the fruits of OS (soybean oil) and OM (mineral oil) treatments exhibiting low acidity in relation to the other treatments. In addition, for the treatments T, H3, H8 and HP, an increase in malic acid concentration at seven days of storage, and subsequent reduction at 14 days, when the fruits were already ripe. This pattern was not observed for the OS and OM treatments, which kept acid concentration almost constant during the storage period, indicating that ripening did not occur to the fruits subjected to treatments based on mineral and soy oils.

TABLE 2. Mean titratable acidity (expressed as % malic acid) of banana fruits undergoing post-harvest treatments and stored for 14 days.

Treat.	'Prata'			'Nanica'			'Maça'		
	Storage Period (days)			Storage Period (days)			Storage Period (days)		
	01	07	14	01	07	14	01	07	14
T	0.60a	1.27b	0.50a	0.79a	0.55a	0.47a	0.52a	0.75abc	0.75ab
H3	0.66a	1.01ab	0.47a	0.79a	0.53a	0.48a	0.48a	0.44a	0.85ab
H8	0.52a	1.28b	0.50a	0.72a	0.53a	0.49a	0.53a	1.02c	0.91b
HP	0.50a	1.26b	0.50a	0.82a	0.55a	0.49a	0.48a	0.82bc	0.89b
OS	0.40a	0.65a	0.42a	0.66a	0.57a	0.44a	0.49a	0.39a	0.45a
OM	0.42a	0.71a	0.57a	0.61a	0.58a	0.57a	0.55a	0.48ab	0.62ab

Means, for each cultivar analyzed, followed by distinct lower-case letters in the columns differ statistically by the Tukey's test ($p<0.05$). T - Control, H3 - water at 50 °C for three minutes; H8 - water at 50 °C for eight minutes; HP - sodium hypochlorite for three minutes; OS - soybean oil for three minutes, and OM - mineral oil for three minutes.

Unlike the standard presented for acidity for most fruits, green banana has low organic acid contents, which increases with the initial activation of maturation, and decreasing as the fruit ripens (CHITARRA & CHITARRA, 2005).

Banana fruits of the 'Nanica' cultivar did not show significant differences in acidity in any of the post-harvest treatments tested throughout the evaluation period (Table 2). However, fruits of the 'Maçã' cultivar showed differences among the post-harvest treatments from the seventh day of storage onwards, with the highest acidity values obtained in the fruits subjected to hydrothermal treatment for eight minutes (H8), which did not differ from the control (T), and the application of hypochlorite (HP), at seven days of storage. This behavior was similar to that found in fruits stored for 14 days.

In the analysis of pH change in banana fruits of the 'Prata' cultivar, the treatments OM (mineral oil) and OS (soybean oil) showed higher pH values at seven days of storage in relation to the other treatments, fact also observed at 14 days for the treatment H8 (Table 3).

Fruits of 'Nanica' cultivar showed no differences in pH values for any of the post-harvest treatments applied. For the 'Maçã' cultivar, differences were observed compared to control fruits only for the hydrothermal treatment for eight minutes (H8) at seven days of storage; at 14 days of storage, the fruits treated with soybean oil (SO) showed higher pH values than the ones submitted to hydrothermal treatment for eight minutes (H8) and immersed in hypochlorite (HP), not differing from the others (Table 3).

TABLE 3. Mean pH of banana fruits undergoing post-harvest treatments and stored for 14 days.

Treat.	'Prata'			'Nanica'			'Maçã'		
	Storage Period (days)			Storage Period (days)			Storage Period (days)		
	01	07	14	01	07	14	01	07	14
T	5.22a	4.44b	4.67b	4.62a	5.18a	5.48a	5.84a	5.18ab	5.30ab
H3	5.40a	4.46b	4.61b	4.60a	5.18a	5.35a	5.85a	5.88a	5.31ab
H8	5.23a	4.48b	4.74ab	4.77a	5.17a	5.42a	5.94a	4.76b	4.80b
HP	5.37a	4.76b	4.70b	4.78a	5.19a	5.36a	5.80a	5.06ab	4.80b
OS	5.52a	5.61a	5.57a	5.05a	5.18a	5.46a	5.81a	5.86a	6.14a
OM	5.39a	4.99a	5.26ab	5.04a	5.14a	5.34a	5.47a	5.70a	5.51ab

Means, for each cultivar analyzed, followed by distinct lower case letters in the columns differ statistically by the Tukey's test ($p<0.05$). T - Control, H3 - water at 50 °C for three minutes; H8 - water at 50 °C for eight minutes; HP - sodium hypochlorite for three minutes; OS - soybean oil for three minutes, and OM - mineral oil for three minutes.

The results presented herein show the effectiveness of using soybean oil and mineral to expand the post-harvest life of 'Prata' banana, since these oil treatments reduced the fruit metabolism. But oils can cause toxicity to the fruit, since darkening of the fruit flesh was observed. JUNQUEIRA et al. (2004), when researching the effects of vegetable oils on post-harvest conservation of mango, observed a blockage of fruit ripening, which was not reversed even after the fruit was stored at 27 ± 1 °C for one week and, although the fruits were healthy and good looking, they had a mild alcohol aroma, suggesting the occurrence of some internal fermentation process, which may also have occurred in this study.

There was an increase in the flesh-peel ratio of the 'Prata' cultivar fruit during the storage for the control and H3, H8 and HP treatments, but the treatments with soybean and mineral oils did not change with storage for this parameter, indicating a delayed ripening (Table 4). The 'Nanica' cultivar showed no difference in the flesh-peel ratio during storage in any of the post-harvest treatments applied. However, the 'Maçã' fruits showed significant differences only at 14 days of storage, with H8 and HP treatments showing the highest values (Table 4).

TABLE 4. Mean flesh-peel ratios of banana fruits undergoing post-harvest treatments and stored for 14 days.

Treat.	'Prata'			'Nanica'			'Maça'		
	Storage Period (days)			Storage Period (days)			Storage Period (days)		
	01	07	14	01	07	14	01	07	14
T	1.22a	1.77a	3.51a	1.35a	2.09a	2.52a	2.42a	2.59a	3.15bc
H3	1.34a	1.72a	3.01a	1.48a	1.63a	2.71a	2.29a	2.48a	2.55a
H8	1.34a	1.98a	3.38a	1.44a	2.20a	2.73a	2.25a	3.21a	4.07a
HP	1.39a	1.87a	3.57a	1.45a	2.09a	2.86a	2.28a	2.60a	4.43a
OS	1.33a	1.91a	1.78b	1.37a	1.77a	2.20a	2.21a	2.57a	2.99bc
OM	1.36a	1.66a	2.14b	1.38a	1.99a	2.46a	2.28a	3.24a	3.63ab

Means, for each cultivar analyzed, followed by distinct lower-case letters in the columns differ statistically by the Tukey's test ($p<0,05$). T - Control, H3 - water at 50 °C for three minutes; H8 - water at 50 °C for eight minutes; HP - sodium hypochlorite for three minutes; OS - soybean oil for three minutes, and OM - mineral oil for three minutes.

According to CARVALHO et al. (1989), the increase in flesh/peel ratio is due to the displacement of water from the peel towards the fruit flesh during the ripening process, resulted from the osmotic pressure gradient from the higher sugar concentration of the flesh relative to the peel. The results presented here are consistent with those observed for soluble solids in all cultivars. This occurs because soluble solids, which are formed mainly of sugars, are the primary responsible for the formation of different osmotic potentials between the flesh and the peel (ADÃO & GLÓRIA, 2005). The averages obtained in the experiment were between 1.35 and 2.86, similar to the numbers reported by CERQUEIRA et al. (2000), and expressing good flesh yield. With regard

to color, at the beginning of the experiment all fruits were in color 01 (completely green), according to subjective visual rating scale used (Table 5). As the time went by, a gradual color change from green to yellow was noticed in most treatments.

In fruits of the cultivar 'Prata', the change in coloration occurred more quickly for the fruits treated with H8 and HP than the control, which suggests that these treatments should not be used to hold ripening, since the visual aspect has a direct influence on consumers' choice (MATSUURA et al., 2004; CHITARRA & CHITARRA, 2005). Only the treatments based on soybean and mineral oils delayed yellowing, but it also caused dark spots on the peel. Fruits of the 'Nanica' cultivar, for all treatments except mineral and soybean oils, were already in the final stage of the color scale at seven days of storage. For the 'Maçã' cultivar, the hydrothermal for eight minutes (H8) and hypochlorite (HP) treatments accelerated maturation the most, when compared to the control. Still for 'Maçã' cultivar, only the application of mineral oil prevented fruit yellowing.

Although the oil-based treatments were effective in delaying the development of yellow color in the fruit, they showed an early softening of the flesh, and especially the treatment based on mineral oil (MO) in the 'Nanica' cultivar. This could be due to the blockage of respiration in the fruit, leading to anaerobic respiration and the formation of toxic compounds, thus reducing the quality of the product (BASTOS & ALBUQUERQUE, 2004). This impairs the use of such treatment by the producers, since quality preservation is one of the most important requirements.

TABLE 5. Means of peel color of 'Prata', 'Nanica' and 'Maçã' banana cultivars undergoing post-harvest treatments and stored for 14 days, according to the visual color scale.

	'Prata' Banana													
	Storage Period (days)													
Treatments	1	2	3	4	5	6	7	8	9	10	11	12	13	14
T	1.0	1.0	1.0	2.0	3.5	4.5	5.5	5.5	6.0	6.0	6.0	6.5	6.5	7.0
H3	1.0	1.0	1.0	1.5	2.0	2.5	4.5	4.5	5.0	6.0	6.0	6.0	6.0	6.5
H8	1.0	1.0	1.5	2.5	4.0	5.5	6.0	6.0	6.0	6.0	6.0	6.5	6.5	7.0
HP	1.0	1.0	2.0	3.5	4.5	5.5	6.0	6.0	6.0	6.0	6.0	6.5	7.0	7.0
OM	1.0	1.0	1.0	1.0	2.0	3.0	3.0	3.0	4.0	4.0	4.5	5.0	5.0	5.0
OS	1.0	1.0	1.0	1.0	2.0	2.5	2.5	3.0	4.0	4.0	4.5	5.0	5.0	5.0
	'Nanica' Banana													
	Storage Period (days)													
Treatments	1	2	3	4	5	6	7	8	9	10	11	12	13	14
T	1.0	4.0	4.0	5.0	6.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
H3	1.0	2.0	3.0	4.0	6.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
H8	1.0	4.0	5.0	6.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
HP	1.0	3.0	4.0	5.0	6.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
OM	1.0	2.0	2.0	2.0	3.0	3.0	4.0	4.0	5.0	5.0	6.0	6.0	6.0	6.0
OS	1.0	2.0	3.0	3.0	4.0	4.0	4.0	4.0	4.0	5.0	5.0	6.0	6.0	6.0
	'Maçã' Banana													
	Storage Period (days)													
Treatments	1	2	3	4	5	6	7	8	9	10	11	12	13	14
T	1.0	2.0	2.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	4.0	5.0	6.0	6.0
H3	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0	3.0	3.0	4.0	5.0
H8	1.0	2.0	2.0	3.0	4.0	4.0	4.0	4.0	5.0	6.0	6.0	7.0	7.0	7.0
HP	1.0	2.0	2.0	5.0	5.0	5.0	6.0	6.0	6.0	7.0	7.0	7.0	7.0	7.0
OM	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
OS	1.0	2.0	2.0	2.0	3.0	3.0	3.0	3.0	3.0	4.0	5.0	5.0	5.0	6.0

Scale: 1 - completely green, 2 - green with yellowing, 3 - more green than yellow, 4 - more yellow than green, 5 - yellow with green tips, 6 - yellow, 7 - yellow with brown spots. T - control, H3 - water at 50 °C for three minutes; H8 - water at 50 °C for eight minutes; HP - sodium hypochlorite for three minutes; OS - soybean oil for three minutes, and OM - mineral oil for three minutes.

CONCLUSIONS

The treatments with chlorinated water at 50 °C for three minutes (H3), drinking water at 50 °C for eight minutes (H8), and sodium hypochlorite with 0.2% of active chlorine for three minutes (HP) were not effective in increasing the shelf-life of bananas, irrespective of the cultivar. Despite treatments based on using soybean (SO) and mineral (OM) oils caused delay in ripening, they may have caused fruit toxicity. Further studies with different concentrations are further required.

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