Disease incidence, physicochemical changes and taste of bananas treated with acetic acid or vinegar

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Disease incidence, physicochemical changes and taste of bananas treated with acetic acid or vinegar.

Abstract — Introduction. The study had two distinct objectives: (1) to determine physicochemical changes and sensory preferences of bananas treated with 0.2% acetic acid, and (2) to explore the possibility of using vinegar available from local retail shops in place of glacial acetic acid, for treating bananas. **Materials and methods**. The effects of either 0.2% acetic acid (made by diluting glacial acetic acid) or diluted vinegar (0.2% titratable acidity) pressure infiltration (1.03×10^5 Pa for 2 min) of bananas (*Musa* AAB 'Embul'), on firmness, peel thickness, pH, titratable acidity, and soluble solids content of the fruit were determined. Sensory preference of treated fruits was evaluated by paired difference evaluations. **Results and discussion**. A significant decrease in soluble solids content in the unripe peel, and an increase in firmness of ripe peel were observed in acetic acid-treated fruits. A decrease in thickness of unripe peel and a decrease in soluble solids in ripe peel were observed in vinegar-treated fruits. Bananas treated with either acetic acid or vinegar were preferred significantly ($p < 0.001$ and $p < 0.05$, respectively). However, in general, unlike when treated with 0.2% acetic acid, vinegar-treated bananas did not show positive changes to the same extent. Artificial vinegar from retailers, which is more freely available than glacial acetic acid, cannot be used to popularize this method of shelf life extension among local banana handlers. **Conclusion**. A 0.2% acetic acid treatment was effective in improving the taste with a high significance, in addition to shelf life extension of bananas. Treatments with vinegar improved the taste significantly but increased disease development.

Sri Lanka / *Musa* (bananas) / keeping quality / postharvest technology / processing / preservatives / quality (fruits)

État sanitaire, changements physico-chimiques et goût des bananes traitées avec de l'acide acétique ou du vinaigre.

Résumé — Introduction. L'étude a eu deux objectifs distincts : (1) de déterminer les changements physico-chimiques et les préférences sensorielles des bananes traitées avec de l'acide acétique à 0,2 %, (2) d'explorer la possibilité d'utiliser du vinaigre acheté localement au lieu de l'acide acétique glacial, pour traiter des bananes. **Matériel et méthodes**. Les effets d'infiltrations sous pression ($1,03 \times 10^5$ Pa pendant 2 min) d'acide acétique à 0,2 % (obtenu par dilution d'acide acétique glacial) ou de vinaigre (à 0,2 % d'acidité titrable) de bananes (*Musa* AAB 'Embul') ont été évalués sur la fermeté, l'épaisseur de la peau, le pH, l'acidité titrable et la teneur en solides solubles du fruit. La qualité des fruits traités a été appréciée par des tests de comparaisons appariées. **Résultats et discussion**. Les fruits traités à l'acide acétique ont montré une diminution significative de la teneur en solides solubles dans la peau des fruits immatures et une augmentation de la fermeté des peaux mûres. Les fruits traités par du vinaigre ont présenté une diminution de l'épaisseur de la peau non mûre et une diminution de la teneur en solides solubles dans les peaux mûres. Les bananes traitées à l'acide acétique ou au vinaigre ont été significativement préférées ($p < 0,001$ et $p < 0,05$, respectivement). Cependant, en général, les bananes traitées par du vinaigre n'ont pas montré autant de changements positifs que celles traitées avec de l'acide acétique à 0,2 %. Le vinaigre artificiel des détaillants, qui est plus librement disponible que l'acide acétique glacial, ne peut donc pas être employé par les manutentionnaires locaux de banane pour vulgariser cette méthode de prolongation de durée de conservation. **Conclusion**. Les traitements avec de l'acide acétique à 0,2 % ont significativement amélioré le goût des bananes traitées, en plus de prolonger la durée de conservation des fruits. Les traitements au vinaigre ont également amélioré de manière significative le goût mais ont augmenté le développement de maladies.

Sri Lanka / *Musa* (bananes) / aptitude à la conservation / technologie après récolte / traitement / agent de conservation / qualité (fruits)

1. Introduction

A considerable amount of bananas are lost due to postharvest diseases. Although 'Embul' bananas (*Musa* ABB) appear to have a good export potential, their short shelf life precludes export of large quantities [1]. Many countries have enforced strict regulations on the use of agrochemicals on fresh produce due to various constraints [2, 3], offering a meager choice of options to enable exportation of large quantities with a reduced risk of disease. Therefore, more research is necessary on alternative, cost-effective methods of increasing the shelf life of bananas, mainly by preventing postharvest diseases. The effect of acetic acid on the shelf life extension of bananas has been investigated by other workers as well [4, 5]. Recently, different methods of postharvest treatments with acetic acid on Embul bananas were tried out in our laboratory [1] and it was found that pressure infiltration was an effective method to increase shelf life [6]. The disease reduction observed in the earlier studies would be of no consequence if the eating quality of bananas was lowered by this treatment. In addition, in the earlier study, the diluted acetic acid was prepared from glacial acetic acid for laboratory use. This method could be popularized among local banana handlers if freely accessible and economically viable resources were available for the treatment of bananas. As an initial step towards this endeavor, the possibility of using diluted vinegar in place of acetic acid was evaluated. Therefore, the present study had two distinct objectives: (1) to determine physicochemical changes and sensory preferences of bananas treated with 0.2% acetic acid, and (2) to explore the possibility of using vinegar available from local retail shops in place of glacial acetic acid, for treating bananas.

2. Materials and methods

2.1. Bananas

Healthy mature green banana fruits (*Musa* AAB, cv. Embul) aged 13 ± 1 weeks were treated within 24 h of harvesting. They were fresh fruits with no record of pre- or postharvest fungicide treatment.

2.2. Experimental design

Each treatment in each experiment described below consisted of four to nine fruits, except in the sensory evaluation studies. Equal numbers of uniform sized and shaped fruits from a hand were assigned randomly to different treatments and the treatments were replicated at least five times. All treatments were done at room temperature and, after treatment, all bananas were stored at ambient conditions [(28 ± 2) °C, (65 ± 5)% relative humidity].

2.3. Pressure infiltration of fruits

Bananas were pressure infiltrated (1.03×10^5 Pa, for 2 min) in either 0.2% acetic acid or diluted vinegar. A 0.2% acetic acid solution (pH 3) was prepared by diluting glacial acetic acid (Assay 99.5%+, Winlab, UK) with distilled water. Vinegar solutions for pressure infiltration were prepared by diluting food grade artificial vinegar obtained from retailers with distilled water. First, the titratable acidity of each vinegar sample was determined by titrating against 1 N NaOH using phenolphthalein as the indicator. Then, having calculated the amount of distilled water to be used to adjust the concentration of titratable acidity to 0.2%, the vinegar was thoroughly mixed with an appropriate amount of distilled water. When purchasing vinegar, only bottles bearing labels indicating that the ingredients were only acetic acid and water were used.

2.4. Physicochemical measurements

The physicochemical parameters described below were determined on banana pressure infiltrated with either 0.2% acetic acid or diluted vinegar (0.2% titratable acidity), within 24 h of treatment (color scale 1), and within 24 h of turning fully yellow (color scale 5) which took 5 to 8 d. They were determined separately for both peel and pulp of control and treated bananas at the two color scales (described below), unless otherwise indicated. Thickness (Vernier Caliper) of the peel followed by firmness (penetrometer, Forestry Suppliers Inc., UK) were measured at three different locations per fruit (stylar-end, middle and stem-end), and the three values were averaged.

Peel firmness was measured as follows. Four pieces of the peel, approximately 2 cm × 4 cm, were removed lengthwise from the fruit and they were kept one on top of the other. The pieces were placed on a firm surface with a hole in the center which enabled the penetrometer to pass through, without interference. Before using the penetrometer, to prevent slipping, the peels were firmly secured with cellotape. The firmness of these peels was measured by aligning the penetrometer so that it passed through the layers of the fruit peel and through the hole. The value thus obtained was divided by four to obtain the average firmness value per peel.

Pulp firmness was measured by slicing the fruit pulp to obtain three 1 cm thick sections and by measuring the firmness of these sections. Titratable acidity and pH were determined as described previously [6]. Soluble solids content (SSC) was measured by grinding *ca.* 1 g of banana tissue finely, centrifuging at 3000 *g*, so that the solids separated out and there was a clear supernatant solution containing the soluble solids. The SSC of the supernatant solution was measured using a refractometer (Leica Model 10430) in Brix degrees.

2.5. Sensory evaluations

A total of 24 panelists was asked to taste coded samples of control and acetic acid-treated ripe bananas (at the color scale 5), from different hands three times. These data were analyzed as a paired difference sensory evaluation test [7]. The panelists were aware that the cultivar of bananas they were tasting was Embul. The above experiment was repeated with bananas treated with diluted vinegar with a total of 24 panelists.

2.6. Comparison of bananas treated with diluted vinegar and acetic acid

Daily observations were made on ripening and disease development of bananas, pressure infiltrated either with 0.2% acetic acid or diluted vinegar (pH 3) starting from the day after the treatment. Ripening was assessed by peel color on a color scale (CS) of 1 to 5 (CS–1: dark green, CS–5: yellow) and disease, on a scale of 1 to 7 (1: disease initiated with isolated lesions of *ca.* < 2 mm diameter being visible, 7: over 50% area covered with lesions) [6].

2.7. Analysis of vinegar samples

Four diluted vinegar samples (0.2% titratable acidity) and 0.2% acetic acid samples were tested for soluble solids content using a refractometer (Leica Model 10430)]. Their total sugar contents were measured using a spectroscopic method [8] (Camspec UV/Visible, Model-M302 spectrophotometer), where sucrose was used as the standard. In addition, the presence of starch in the vinegar before and after diluting was detected by color change with a solution of iodine in potassium iodide (1g/2 g, [I_2/KI] in 300 mL water).

3. Results

No changes were observed in the physicochemical characteristics of the edible pulp of bananas after 0.2% acetic acid treatment (*table I*). The firmness of ripe banana peel was significantly ($p < 0.05$) higher in 0.2% acetic acid-treated bananas and that of unripe pulp was significantly high in diluted vinegar-treated bananas. The 0.2% acetic acid-treated ripe bananas had a stiffer peel, exhibited by not drooping down like those of controls, when the bananas were peeled. Soluble solids contents were significantly lower in the unripe 0.2% acetic acid-treated peel and that of ripe peel of diluted vinegar-treated bananas. Peel thickness was significantly lower in the unripe diluted vinegar-treated bananas. None of the other physicochemical parameters were affected by the treatments.

Table I.
Physicochemical parameters of pulp and peel tissues of unripe mature green bananas of color scale 1 and ripe bananas at color scale 5, pressure infiltrated with 0.2% acetic acid or diluted vinegar as compared to the corresponding controls.

Parameter	Unripe mature green bananas				Ripe bananas			
	Peel		Pulp		Peel		Pulp	
	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control
Thickness (mm)								
with 0.2% acetic acid	1.97 a	1.90 a	Not applicable	Not applicable	0.66 a	0.53 a	Not applicable	Not applicable
with diluted vinegar	2.45 d	2.68 c	Not applicable	Not applicable	1.63 c	1.80 c	Not applicable	Not applicable
Firmness ($kg \times cm^{-2}$)								
with 0.2% acetic acid	1.06 a	1.03 a	1.60 a	1.58 a	0.36 a	0.20 b	0.32 a	0.30 a
with diluted vinegar	1.01 c	1.04 c	1.86 c	1.63 d	0.24 c	0.35 c	0.41 c	0.47 c
pH								
with 0.2% acetic acid	5.35 a	5.48 a	4.98 a	4.96 a	5.70 a	5.85 a	4.64 a	4.77 a
with diluted vinegar	5.54 c	5.42 c	4.96 c	4.93 c	5.87 c	5.71 c	4.57 c	4.58 c
Titratable acidity ($H^+ \times g^{-1}$)								
with 0.2% acetic acid	0.25 a	0.17 a	0.25 a	0.23 a	0.33 a	0.31 a	0.65 a	0.59 a
with diluted vinegar	0.27 c	0.25 c	0.48 c	0.45 c	0.37 c	0.35 c	0.96 c	0.92 c
Soluble solids content (°Brix)								
with 0.2% acetic acid	1.48 b	2.22 a	2.84 a	2.50 a	12.06 a	13.46 a	23.37 a	23.30 a
with diluted vinegar	2.46 c	2.52 c	11.80 c	10.86 c	9.54 d	12.01 c	22.20 a	21.78 a

Numbers followed by the same letter for each pair of means for treated and control samples are not significantly different by a pooled *t*-test ($p < 0.05$).

In vinegar-infiltrated bananas, neither the peel color nor the disease incidence were affected significantly ($p < 0.05$) by the treatment. The disease score differences between treated bananas and the corresponding controls showed a negative trend, unlike those of bananas treated by 0.2% acetic acid (*figure 1*). There was no indication for the presence of starch, sugar or soluble solids in the vinegar samples.

There was a highly significant ($p = 0.001$) preference for 0.2% acetic acid-treated bananas. The sensory evaluation of 0.2% acetic acid-infiltrated bananas by 24 tasters showed that the treated sample tasted better than the control. The 21 panelists who preferred the treated bananas commented that they had a sharper flavor. The three panelists who did not like the treated bananas commented that the taste was not objectionable, but they tasted less sour, and this was not expected of "Sour" ("Embul" means sour in the local language, Sinhalese) bananas. The preference of vinegar-treated bananas was significant at $p = 0.05$. Of the 24 tasters, six consistently preferred treated bananas while two consistently preferred control bananas and four could not distinguish a difference.

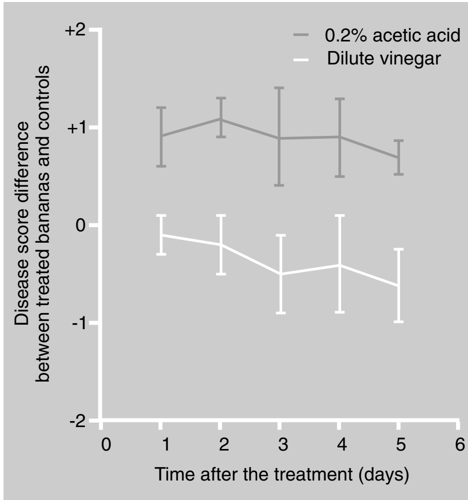

Figure 1.
Daily disease score differences of bananas pressure infiltrated with either 0.2% acetic acid or diluted vinegar (pH 3) as compared to the respective controls. Disease was assessed on a scale of 1 to 7 (1: disease initiated with isolated lesions of *ca.* < 2 mm diameter being visible, 7: over 50% area covered with lesions).

4. Discussion

The same physicochemical parameters that changed due to the 0.2% acetic acid treatment changed due to the vinegar treatment. However, the stages at which such changes were observed were different in the two protocols, as stated above (*table I*). The only difference was in peel thickness observed due to the vinegar treatment which was not observed when treated with acetic acid. The experiments on the physicochemical changes of banana due to diluted vinegar treatment were conducted 3 years after conducting the rest of the experiments discussed in this research paper and these data were generated by a different investigator. In spite of obtaining bananas from the same fields as for the previous experiments, generally the peel thickness values were higher in the diluted vinegar infiltration experiment (*table I*). This could indicate user biases in handling the Vernier caliper as these data were generated by a different investigator. On the whole, during the time the experiment on the physicochemical parameters of vinegar-treated bananas was conducted, unusually hot, humid weather conditions [(28.5 ± 0.5) °C, (67 ± 0.5)% relative humidity) prevailed. This may explain the higher soluble solids content value of the unripe pulp and higher levels of acidity in vinegar-treated samples.

In an earlier study [6], it was observed that the 0.2% acetic acid treatment caused a firmness increase in the intact bananas. The present study shows that this increase in firmness is only on the peel with no detectable effect on the pulp. Although the lower soluble solids content in the 0.2% acetic acid-treated peel, within 24 h of treatment, could have been explained by a dilution effect caused by the recently infiltrated solution into the tissues, such a phenomenon was not observed with bananas treated with vinegar. In comparison with this, it is intriguing however that the soluble solids content of vinegar-treated peel shows a significantly lower value at CS–5. None of the physicochemical parameters of the edible part (pulp at CS–5) were affected by the treatments. However, results of the sensory evaluation study show that the 0.2% acetic acid-treated bananas are preferred although the reason could not be detected from the physicochemical tests carried out. The earlier study suggested that the acid treatments influenced the biochemistry of the fruit, perhaps through affecting the ethylene induced by the ripening system [6]. As there were no detectable changes in the physicochemical parameters of the edible pulp, there is a strong possibility that both treatments induce volatile flavor compound formation which affects the organoleptic properties of the fruit, as detected by the panelists of the sensory evaluation studies. Acetates have been found among volatile flavor compounds in bananas [9]. In an earlier study on apples, the application of vapors of several carboxylic acids including acetic acid on the fruit caused the production of volatile esters by the fruit [10]. However, it appears that the relative purity of diluted vinegar in comparison to glacial acetic acid prevents the bananas from achieving the same degree of preference. The trend in changes in physicochemical parameters by both treatments is comparable.

The ability of acetic acid and vinegar to increase the fruit's shelf life has been demonstrated in several studies [5, 11–15]. However, the present study demonstrated that the 0.2% acetic acid made from glacial acetic acid could not be replaced with vinegar available at retail shops in Sri Lanka to achieve the same effect on bananas by pressure infiltration. For a better representation of results, in presenting the data in *figure 1*, day 1 was considered to be the day when diseases appeared in the control or in the fruits treated. We have shown that the concentration of acetic acid for pressure infiltration of Embul bananas should not be above or below 0.2% acetic acid [6]. Therefore, all vinegar samples obtained were tested for their titratable acidity, and diluted to a concentration of 0.2% acetic acid by adding the appropriate amount of water.

In Sri Lanka, artificial vinegar should not be less than 4% (weight per volume) acetic acid [16]. Internationally, vinegar is 4% to 12% acetic acid. In addition to acetic acid, other organic acids and esters are present in vinegar [17]. The comparative analysis carried out with vinegar and diluted acetic acid solutions did not show sugar, starch or soluble solids. However, it appears that trace amounts of substances other than acetic acid in commercial vinegar had a negative effect on bananas, in spite of a similar trend in the data generated when using either 0.2% acetic acid prepared from glacial acetic acid or diluted vinegar at 0.2% titratable acidity.

5. Conclusions

Pressure infiltration of Embul bananas with 0.2% acetic acid does not appear to affect the firmness, pH, titratable acidity or soluble solids of the edible ripe pulp. The use of diluted artificial vinegar at a concentration of 0.2% titratable acidity showed a parallel trend in physicochemical attributes. However, unlike acetic acid treatment, the vinegar treatment did not help to reduce postharvest disease incidence. The taste of treated bananas were preferred over control bananas and the degree of preference for acetic acid-treated bananas was higher. Use of diluted artificial vinegar with a titratable acidity of 0.2% cannot achieve the same degree of quality achieved by treating with 0.2% acetic acid.

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Impacto sanitario, cambios fisicoquímicos y de sabor de bananos tratados con ácido acético o vinagre.

Resumen — **Introducción**. El estudio tenía dos objetivos distintos: (1) determinar los cambios fisicoquímicos y las preferencias sensoriales de bananos tratados con ácido acético al 0,2%, (2) explorar la posible utilización de vinagre comprado localmente en vez del ácido acético glacial, para tratar los bananos. **Material y métodos**. Los efectos de infiltraciones bajo presión (1.03×10^5 Pa durante 2 min) de ácido acético al 0,2% (obtenido por dilución de ácido acético glacial) o de vinagre (al 0,2% de acidez titulable) en bananos (*Musa* AAB 'Embul') se evaluaron en cuanto a la consistencia, grosor de la piel, pH, acidez titulable y contenido en sólidos solubles del fruto. La preferencia sensorial de los frutos tratados se valoró mediante tests de comparación pareados. **Resultados y discusión**. Los frutos tratados con ácido acético mostraron una disminución significativa del contenido de sólidos solubles en la piel de frutos inmaduros y un aumento de la consistencia de las pieles maduras. Los frutos tratados con vinagre mostraron una disminución del grosor de la piel no madura y una disminución del contenido de sólidos solubles en las pieles maduras. Los bananos tratados con ácido acético o vinagre se prefirieron de forma significativa ($p < 0,001$ y $p < 0,05$, respectivamente). Sin embargo, en general, los bananos tratados con vinagre no mostraron tantos cambios positivos como los que fueron tratados con ácido acético al 0,2%. El vinagre artificial de los minoristas, cuya disponibilidad es superior a la del ácido acético glacial, no puede, por tanto, ser empleado por los manipuladores locales de banano para extender este método de prolongación de la duración de conservación. **Conclusión**. Los tratamientos con ácido acético al 0,2% aumentaron notablemente el sabor de los bananos tratados, además de prolongar la duración de conservación de los frutos. Los tratamientos con vinagre mejoraron notablemente el sabor pero incrementaron el desarrollo de enfermedades.

Sri Lanka / *Musa* (bananas) / aptitud para la conservación / tecnología postcosecha / procesamiento / preservadores / calidad (frutas)