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EFFECTS OF ACIDIC ELECTROLYZED WATER WITH DIFFERENT TEMPERATURES ON MICROBIAL CONTROL AND QUALITY OF FRESH-CUT BANANA LEAVES DURING STORAGE

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ABSTRACT: The effects of acidic electrolyzed water (AEW) on microbial control and quality of fresh-cut banana leaves during storage were studied. Fresh-cut banana leaves cv. Tanee (TN) and cv. Klauay Namwa (KN) were sanitized with either 4°C or 27±2°C of 50 ppm acidic AEW for various times (10, 20 and 30 minutes). The sanitized sample was packed in polyethylene (PE) bag and storage at 5±2◦C for 7 days, before transferred to 27±2°C to evaluate their shelf-life. The results showed that sanitization with 4°C and 27±2°C of AEW for 30 minutes were completely eliminated the microorganism on fresh-cut samples from both cultivars. Nevertheless, these contact time had the highest loss of more than 78% after 5 days at room temperature. Sanitized samples with AEW for 20 and 30 minutes effectively delayed the microbial growth, therefore the amount of microorganism remained below EU Regulation (EC) No. 2073/2005 criteria after storage. The shelf-life of fresh-cut samples was 13 days and terminated after their visual appearance such as yellowing or browning occurred. Fresh-cut samples sanitization with both treatments had similar quality changes such as color changes and chlorophyll contents. However, sanitization with 4°C AEW had lower weight loss than those of with 27°C AEW during storage at room temperature. It also effectively reduced the microorganism on fresh-cut samples and had the lowest loss which was 22%. Therefore, sanitization with 4°C AEW for 20 minutes was an appropriate method to sanitized fresh-cut banana leaves for both cultivars.

Keywords: Sanitization, Fresh-cut, Acidic electrolyzed water, Banana leaves

1. INTRODUCTION

Banana leaves have been used for food wrapped and decoration since the ancient times due to their appearance and aroma made food is appetizing. Nowadays cut banana leaves are widely used for food wrapping and decoration in restaurants both in Thailand and overseas. The banana leaves exported from Thailand was frozen. The bag of banana leaves contained at least 5 kilograms of the cut banana leaf sheath. However there was less than 50% can be used from each bag, and the rest became waste because of the trimming to suitable for consumer purposes.

Today's consumer is demanding for foods that require a minimal process, for example, Fresh cut fruit and vegetables, initially called minimally processed or lightly processed products, are those that have been trimmed, peeled and/or cut into 100% usable product that is bagged or pre-packed and kept at refrigerated storage. These foods are in great demand because of their convenience [1]. The food service industry and restaurants are the major users of minimally processed products [2]. However, fresh-cut products deteriorate quickly and have limited shelf-life [3]. Major problems of deterioration in fresh-cut products associated with the microbial growth in the products. Raw fresh produce could be contaminated with pathogens during harvesting through fecal material (manure, both of human and animal origin), human handling, washing procedure, processing equipment, transportation, and distribution [4].

Electrolyzed Water (EW) has been used as a sanitizer in the food industry for many years [5][6]. AEW is conventionally generated by electrolysis of aqueous sodium chloride (0.5–1.0% NaCl), and an electrolyzed acidic solution is produced at the anode. Acidic Electrolyzed water (AEW) has a strong bactericidal effect on pathogenic and spoilage microorganisms [7][8]. This effect is attributed to its low pH (2.1–4.5), high oxidation-reduction potential (higher than 1000 mV), and the presence of active oxidizers such as hypochlorous acid [9][10]. Previously, Issa-Zacharia *et al.* [11] reported that Slightly AEW technology had stronger decontamination ability than other sanitizers in fresh-cut lettuce and carrot. Tomas-Callejas *et al.* [12] also reported that acidic electrolyzed water has the most effective on microbial reduction of mizuna baby leaves compared with other sanitizers.

There are numerous reports which describe the efficacy of AEW on the microbial growth on fruit and vegetables [13][14]. Therefore, this sanitizer

should effectively remove microbial contamination on the fresh-cut banana leaves too. The purpose of the current study was to evaluate the efficacy of 4°C and 27+2°C AEW at a different time (10, 20 and 30 minutes) for controlling microbial growth and their effect on quality of fresh-cut banana leaves during storage at low temperature.

2. MATERIALS AND METHODS

2.1 Plant Materials

Banana leaves cv. Tanee (*Musa balbisiana* Colla.) and cv. Klauy name (*M. sapientum* Linn.) from Muang mai market (Chaing mai, Thailand) were transported to the postharvest laboratory (Chiangmai University, Thailand). The leaves were physically inspected and defective parts such as mechanical damage or yellowing pieces were removed. Selected leaves were cut into 7 inches diameter of the circle for the following study.

2.2 Processing and Storage Conditions

The fresh-cut samples were sanitized with either 4°C or 27°C acidic electrolyzed water (final chlorine concentration 50 ppm, pH 2-4) for 10, 20, 30 minutes. After air-dried, sanitized samples were placed in PE bags. All steps were performed under sanitary conditions. Samples were stored at 5±2°C for 7 days and then transfer at room temperature (27±2°C) for 8 days. For each treatment, ten replicated were used. The microbial growth, quality changes such as chlorophyll content, the percentage of weight loss and color changes of the sample were evaluated on the day 0) and after 3, 5, 7 days of storage at 5±2°C and after 9, 11, 13, 15 days at room temperature.

2.3 Microbial Content Determination

Samples were examined according to the standard methods for the microbiological analysis. Thirty-nine grams of potato dextrose agar (PDA) was suspended in 1 L distilled water and sterilizing at 120 psi pressure for an hour. Spread plate technique after serial dilution in sterile distilled water was used in all tests. The first dilution was prepared by shaking 5x5 cm^2 of leaf samples with 5.8 ml of sterile distilled water and further dilutions were made according to the need. Ten plates were used for each treatment. Total viable plate count agar was determined after incubation at 37°C for 48 hours.

2.4 Quality Changes Determination

2.4.1 Weight loss

The weight loss of samples was determined by weighing each fresh-cut leaf samples on the day after each period of storage using a laboratory level weighing balance. Values are reported as a percentage of weight loss per initial sample weight.

2.4.2 Color evaluation

The upper and lower surface color of fresh-cut banana leaves were determined using a HunterLab colourimeter (ColourFlex, Hunter Associates Laboratory, Inc., VA, USA). The color was measured using the CIE L*, a*, and b* scale. The color values were expressed as L* (whiteness or brightness /darkness), a* (redness/greenness) and b* (yellowness/blueness) at any time, respectively. Each sample was scanned at three different locations to determine the average L*, a* and b* values during the measurements.

2.4.3 Chlorophyll content

The chlorophyll pigments were extracted from 5 g. of the fresh-cut sample with 20 ml acetone for 20 minutes and then filter with filter paper No.1. Quantification was performed in a spectrophotometer (UV-1603 Shimadzu Tokyo, Japan) The total chlorophyll, chlorophyll a and chlorophyll b content was expressed as mg per 100 g of fresh weight using [15] method.

2.5 Experimental Design and Statistical Analysis

The experimental units were bags and there were ten replications per sanitizing treatment, application system and evaluation period. ANOVA tests were used depending on the homogeneity of the variances. The differences among various treatments by Tukey's range test ($P<0.05$) using SPSS version 14 [16].

3. RESULTS AND DISCUSSION

3.1 Microbial Content Determination

The initial total microorganism on the TN leaves was 313.33 and the KN leaves were 434.44 CFU/cm^2. Cleaning with distilled water reduced the microbial population to 48.75 (TN). and 90.93 (KN) CFU/cm^2 The longer contact time, the higher effective of microorganism inactivation (Fig. 1,2) for both temperatures.

The maximum reduction of total microorganism on fresh-cut banana leaves was observed by AEW 4°C for 30 minutes which were completely eliminated the microorganism on fresh-cut samples from both cultivars at day 0. The number of microorganisms slightly increased to 5.00 (TN) and 6.75 (KN) CFU/cm^2 after 7 days storage at 5±2°C.

Sanitization with 4°C AEW for 20 minutes was significantly reduced the total microbial content on

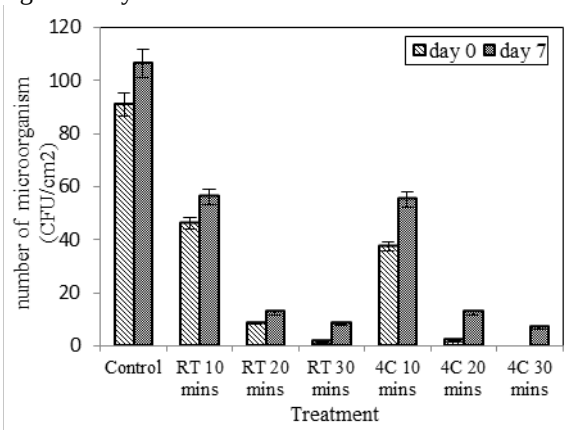

Fig. 1 The number of microorganism on TN fresh-cut banana leaves after sanitization with AEW and after storage at 5±2°C for 7 days.

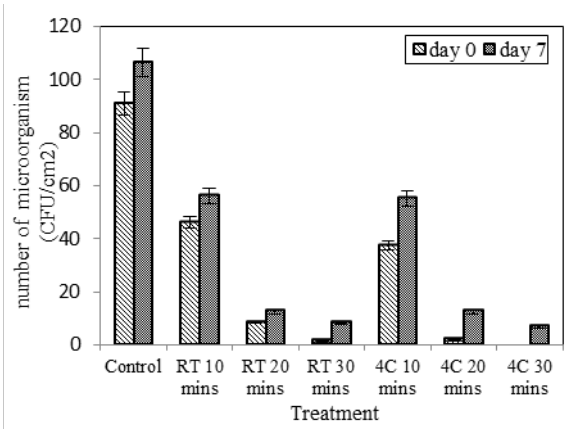

Fig. 2 The number of microorganism on KN fresh-cut banana leaves after sanitization with AEW and storage at 5±2°C for 7 days.

both cultivars to 1.5 (TN) and 1.77 (KN) CFU/cm^2. Although the number of microbial population in the leaves sample increased to 8.75 (TN) and 12.5 (KN) CFU/cm^2 after 7 days storage. [Fig 1,2], they were below the EU Regulation and acceptable for use as fresh cut. The temperature of sanitizer and washing time were factors that affected the microbial efficacy of AEW [17]. Koide *et al.* [18] also reported that when fresh-cut cabbage was wash by slightly AEW, the reduction was found in total bacteria count. The number of bacteria increased during storage. Similar results were reported by Beltran *et al* [19] and Lopez-Galvez [20] that found the microbial growth on fresh-cut products even stored at low temperature.

3.2 Quality Changes Determination

In this study, the shelf life of a fresh-cut banana leaves were 13 days regardless of their visual

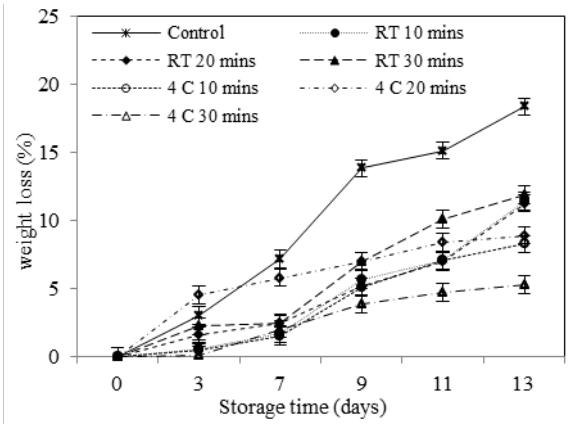

Fig. 3 Effects of AEW on % weight loss of TN fresh-cut banana leaf storage at 5±2°C for 7 days and 27±2°C for 6 days.

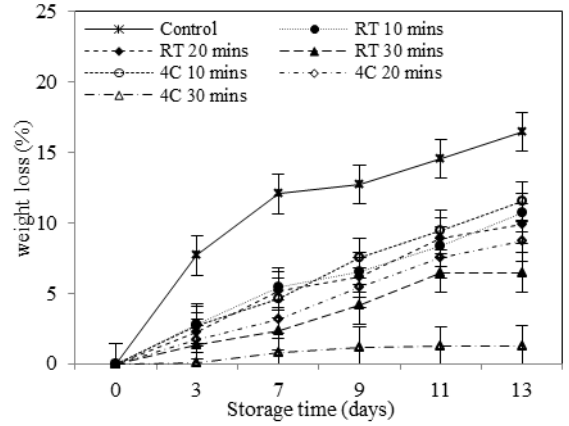

Fig. 4 Effects of AEW on % weight loss of KN fresh-cut banana leaf storage at 5±2°C for 7 days and 27±2°C for 6 days.

appearances such as the occurrence of yellowing or browning. No difference in the appearance quality was observed among sanitizing agents after washing on day 0 and after7 days of storage at 5±2°C. However, the visual appearance rapidly deteriorated after transferred to 27±2°C. Fresh-cut banana leaves that sanitized with 4°C AEW had a lower quality loss than fresh-cut banana leaves that sanitized with 27°C AEW. The appearance of fresh-cut banana leaves sanitized with 4°C AEW for 30 minutes quickly declined and more than 78% of the sample had to be discarded. The lowest quality loss was found on fresh-cut banana leaves sanitized with 4°C AEW for 20 minutes which were 22%. Park *et al.* [22] also report that longer treatment times adversely affect the general appearance and nutritional content of the product.

The percentage of weight loss from all treatment slightly increased during storage at 5°C for 7 days

Table 1 Changes of surface color and chlorophyll content in TN fresh-cut banana leaves after sanitized with electrolyzed water and storage for 13 days.

treatment	Upper surface color			Lower surface color			Chlorophyll content		
	L*	a*	b*	L*	a*	b*	total	a	b
control	37.32a	-7.29a	24.58a	48.49a	-7.16a	26.59a	0.14 a	0.09a	0.01a
RT-AEW									
-10 mins	42.36a	-5.16a	24.65a	52.13a	-7.52a	31.53a	0.14 a	0.10a	0.02a
-20 mins	35.59a	-6.16a	24.14a	47.12a	-6.77a	25.26a	0.19 a	0.10a	0.08a
- 30 mins	49.08a	-6.54a	28.23a	50.55a	-6.50a	27.53a	0.14 a	0.10a	0.04a
4°C-AEW									
-10 mins	34.13a	-7.05a	23.65a	47.51a	-7.83a	27.05a	0.15 a	0.07a	0.06a
-20 mins	35.69a	-7.16a	24.46a	47.22a	-8.07a	26.12a	0.17a	0.10a	0.06a
- 30 mins	35.55a	-7.93a	23.95a	47.95a	-7.46a	26.22a	0.16a	0.10a	0.05a

Note: The data followed by the same letter within the column are not significantly different (P<0.05)

Table 2 Changes of surface color and chlorophyll content in KN fresh-cut banana leaves after sanitized with electrolyzed water and storage for 13 days.

treatment	Upper surface color			Lower surface color			Chlorophyll content		
	L*	a*	b*	L*	a*	b*	total	a	b
control	43.35a	-9.28a	26.67a	54.66a	-6.54a	30.13a	0.06a	0.04a	0.02a
RT-AEW									
-10 mins	40.16a	-9.42a	27.21a	59.17a	-6.16a	31.51a	0.06a	0.05a	0.01a
-20 mins	52.12a	-8.24a	31.21a	57.84a	-5.16a	31.45a	0.07a	0.05a	0.01a
- 30 mins	50.42a	-8.15a	31.30a	54.91a	-6.52a	32.55a	0.07a	0.05a	0.01a
4°C-AEW									
-10 mins	44.15a	-8.54a	27.65a	52.23a	-8.63a	32.01a	0.06a	0.04a	0.01a
-20 mins	41.20a	-9.16a	32.20a	53.13a	-6.79a	30.01a	0.06a	0.05a	0.01a
- 30 mins	41.16a	-9.12a	25.22a	52.52a	-6.15a	30.45a	0.09a	0.06a	0.02a

Note: The data followed by the same letter within the column are not significantly different (P<0.05)

and they rapidly increased after transferred to 27±2°C. There were no significant differences among AEW treatments during storage period from both on TN and KN fresh-cut banana leaves [Fig.3,4].

The surface color of fresh-cut banana leaves both upper and lower sides were evaluated. The L*, a*, and b* value exhibited no significant differences among washing treatments after storage for 13 days. Furthermore, the chlorophyll contents of fresh-cut banana leaves from each sanitizing temperature exhibited no significant differences after storage for 13 days [table1, 2]. Therefore, the temperatures of the sanitizers had no effect on the color changes and the chlorophyll content of the fresh-cut banana leaves. This finding agreed with a previous study that no significant differences in weight loss, color and chlorophyll content were found on fresh-cut banana leaves after sanitized with sanitizers [23]. In addition, Martinez-Sanchez *et al* [24] reported that sanitized rocket leaves with sanitizers before storage did not affect the quality such as color and chlorophyll content during storage. Similarly, results were reported by Izumi [25] on mizuna baby leaves and Wang *et al*. [26] on cilantro leaves. However, the effect of sanitization treatment on fresh-cut product quality depends on the fruit or vegetable, time of exposure, and concentration of sanitizer [27].

4. CONCLUSIONS

Sanitization with 4°C AEW for 20 minutes was an appropriate method to sanitized fresh-cut banana leaves for both cultivars. The treatment used had the least effect on the appearance quality of fresh-cut banana leaves such as weight loss, surface color and chlorophyll content after washing and storage. Therefore, this method will be applied in the sanitizing process of fresh-cut banana leaves for export in the foreign market.

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