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Impact of Electrostatic Atomized Water Particles Treatment on Chlorophyll Degradation and Delay Ripening in a Thai Banana (*Musa* × *paradisiaca*, cv. 'Namwa' Banana) during Storage

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Electrostatic atomized water particles (EAWPs) treatment was applied to investigate its effect on chlorophyll (Chl) degradation and ripening delay in 'Namwa' bananas. Banana fruits were pretreated with EAWPs generated from a device (Panasonic F-GMK01) for 0 (control), 0.5, 1.0, 1.5, and 3.0 h in a closed 50 L container, and then kept in perforated polypropylene plastic bags and stored at ambient temperature (25 ± 2°C) under dark conditions. The results showed that 1.0 h-EAWPs treatment best retained peel greenness with a significantly higher hue angle and lower *L value than other treatments on day 6. Also, the 1.0 h-EAWPs treatment maintained the total Chl content, firmness, total soluble solids (TSS) and delayed the ripening index (RI) of fruit accompanied by a delayed climacteric rise in ethylene and respiration rate compared to the control. It was found that the 1.0 h-EAWP treatment induced accumulations of nitric oxide (NO) in peel tissues and suppressed the activities of Chl-degrading enzymes (chlorophyllase, Mg-dechelatase, Chl-degrading peroxidase, and pheophytinase) in the peel. Furthermore, Chl derivatives levels (chlorophyllide *a*, pheophobide *a*, 13^2-hydroxychlorophyll *a*, and pheophytin *a*) were higher in fruits treated with EAWPs than the control fruits. The results suggest that EAWPs technology could be an alternative approach to delay Chl degradation and ripening in 'Namwa' bananas.**

Key Words: 'Namwa' banana, chlorophyll degradation, electrostatic atomized water particles, nitric oxide accumulations.

Introduction

The 'Namwa' banana (*Musa* × *paradisiaca*) is an important commercial crop in Thailand and is very popular, being consumed locally and internationally (Ploetz et al., 2007; Youryon and Supapvanich, 2016). Recently, the demand for 'Namwa' bananas has increased in global markets, including China, Hong Kong, and Japan (Suvittawat et al., 2014), owing to its abundance of vitamin, minerals, and phenolics (Bennett et al., 2010). Banana is a climacteric fruit that is able to produce ethylene after harvest to trigger and accelerate the ripening

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process (Reid, 1992; Siriboon and Banlusilp, 2004). During postharvest storage, the green color of 'Namwa' banana peel turns to yellow quickly, resulting in a short storage-life of less than two days (Salaemae et al., 2021; Seymour et al., 1993). This loss of greenness in horticultural crops occurs with the progress of senescence, resulting from chlorophyll (Chl) degradation (Jitareerat et al., 2015). This problem is a major concern as agricultural produce may ripen before reaching distributors and consumers. Therefore, postharvest techniques are needed to extend the storage life and maintain the quality of agricultural produce. Previous techniques relied on chemical methods to improve the shelf life of banana fruits. However, concern about these chemicals harming human health has encouraged researchers to look into non-chemical treatments as an alternative.

One of the non-chemical treatments is to induce stress in the produce. There are several postharvest stress treatments to suppress senescence and delay Chl degradation in horticultural crops, including heat treatment, irradiation, and others (Lurie, 1998; Sivakumar and Fallik, 2013; Yamauchi, 2015). Ummarat et al. (2011) reported that hot water treatment at 50°C for 10 min efficiently delayed ripening, retarded Chl *a* and *b*, total Chl breakdown, and increased antioxidant activity of banana fruit. Similarly, UV-C irradiation delayed yellowing and Chl degradation due to the inhibition of chlorophyllase and Chl-degrading peroxidase activities in banana fruit (Pongprasert et al., 2011). With advancements in technology, electrostatic atomized water particles (EAWPs) have been introduced for agricultural application. EAWPs is a technology that can produce reactive oxygen species (ROS) such as superoxide anions, hydroxyl radicals, hydrogen peroxide (H_2O_2), nitric oxide (NO), nitrate, and nitrite ions by electrostatic atomization of moisture (Shimokage et al., 2005; Yamauchi et al., 2014). This technology has been applied to preserve the greenness of citrus fruit cultivars such as green Nagato-yuzukichi and green yuzu (Yamauchi et al., 2014). Nomura et al. (2017) reported that EAWPs treatment delayed de-greening of broccoli florets by inhibiting chlorophyll degradation. Similarly, EAWPs treatment of mangosteen fruit suppressed the de-greening of calyx by reducing Chl-degrading enzyme activities and reducing the levels of Chl derivatives (Kaewsuksaeng et al., 2019). Recent research has also found that EAWPs treatment was able to improve the antioxidative system and protect cells from oxidative stress damage resulting in delayed senescence and peel blackening in 'Namwa' banana (Salaemae et al., 2021). In addition, EAWPs treatment not only maintained postharvest quality of agricultural produce, but also the accumulation of NO, which effective in controlling postharvest diseases such as gray mold in tomato (Imada et al., 2015). NO acts as an important signaling molecule in plants and plays a role in plant responses to stresses (Lamattina et al., 2003; Salgado et al., 2013); for example, the accumulation of NO increased the Chl content in pea leaves and retarded the Chl degradation in phytophthora-infected potato leaves. (Laxalt et al., 1997). These previous studies led us to hypothesize that EAWPs treatment may induce NO accumulation and consequently reduce Chl degradation in 'Namwa' bananas. Moreover, EAWPs treatment may also delay the ripening and maintain the quality of 'Namwa' bananas during postharvest storage.

Materials and Methods

Banana fruit samples

Banana fruit (*Musa* × *paradisiaca* cv. 'Namwa' banana) were harvested at the commercial mature green stage (70% maturity). The fruit were selected based on their uniformity of weight, peel color, and absence of physical damage or any defects due to plant pests. Each banana hand was cut into individual fingers.

Electrostatic atomized water particles (EAWPs) treatment

The banana fruit were divided into five treatment groups and pre-treated with EAWPs at 0.5, 1.0, 1.5 and 3.0 h. Non-treated EAWPs fruits were used as a control. EAWPs treatment was performed according to a method previously described by Salaemae et al. (2021). The fruit were separated from the banana hand into individual fruits. Thirty fruits were placed in a closed container of 50 L and treated with EAWPs. The control fruits were enclosed in the same type of containers without the device. All fruit samples were kept in polypropylene plastic bags (0.03 mm thick, size 200 × 300 mm, with two 5 mm holes) and stored at room temperature (25 ± 2°C) with 80–90% RH under a dark condition for 8 d. During storage, the samples were evaluated for peel color changes (*L** value and hue angle) and the optimal EAWPs treatment condition was chosen. From the preliminary study, EAWPs treatment for 1.0 h was selected for further study to be compared with the untreated control. The banana samples were randomly collected to examine any changes in postharvest physiology every other day throughout the storage period. Each treatment consisted of five replications and each replicate contained four fruits.

Peel color and total chlorophyll content

The peel color of banana fruit was measured using a colorimeter (Model NF 777; Nippon Denshoku, Japan) to determine the *L** and hue angle values. Three locations were taken from each fruit: the top, middle, and bottom of the banana.

Total chlorophyll content was analyzed according to the method of Moran (1982). Banana peel weighing 0.5 g was extracted in 10 mL of *N,N*-dimethylformamide and incubated at 4°C in the dark overnight. The extracts were filtered with Whatman No. 1 filter paper. Then,