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ผลของน้ำอิเล็กโทรไลต์ที่เป็นกรดและรังสีอัลตราไวโอเลตซี ต่อเชื้อราที่พื้นผิวและคุณภาพของสับปะรดภูแล
Effects of Acidic Electrolyzed Water and Ultraviolet-C on Surface Mould and Quality of 'Phulae' Pineapple

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บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาผลของการจุ่มผลสับปะรดในน้ำอิเล็กโทรไลต์ที่เป็นกรด (AEW) เป็นระยะเวลา 10 นาที และการฉายรังสี UV-C เป็นระยะเวลา 2.75 นาที (UV-C 13.2 kJ.m^{-2}) หรือ 8.25 นาที (39.6 kJ.m^{-2}) ต่อการลดความรุนแรงของเชื้อราที่ผิวและการเปลี่ยนแปลงคุณภาพสับปะรดพันธุ์ภูแล ชุดการทดลองแบ่งออกเป็น ชุดที่จุ่มใน 300 ppm AEW ชุดที่ฉายรังสี 13.2 kJ.m^{-2} UV-C ชุดที่ฉายรังสี UV-C 39.6 kJ.m^{-2} ชุดที่จุ่มด้วย AEW 300 ppm + UV-C 13.2 kJ.m^{-2} ชุดที่จุ่มด้วย AEW 300 ppm + UV-C 39.6 kJ.m^{-2} และชุดควบคุมคือสับปะรดที่ไม่ได้รับทรีทเมนต์ใด หลังจากนั้นนำไปเก็บรักษาที่อุณหภูมิ 13±1 °C เป็นเวลา 28 วัน พบว่าตัวอย่างในชุดควบคุมมีความรุนแรงของการเกิดเชื้อราสูงสุดคิดเป็นร้อยละ 76.67±1.67 ในขณะที่ชุดที่จุ่มด้วย AEW 300 ppm + UV-C 39.6 kJ.m^{-2} พบต่ำสุดร้อยละ 49.17±5.83 เมื่อเก็บรักษา 21 วัน ชุดการทดลองของสับปะรดที่จุ่มด้วย AEW 300 ppm + UV-C 39.6 kJ.m^{-2} มีปริมาณสารฟีนอลิกทั้งหมด ปริมาณฟลาโวนอยด์ทั้งหมด และกิจกรรมต้านอนุมูลอิสระ (DPPH และ FRAP) มากกว่าสับปะรดในชุดควบคุม ดังนั้น การจุ่มผลสับปะรดด้วยน้ำ AEW ความเข้มข้น 300 ppm ร่วมกับการฉายรังสี UV-C ความเข้มข้น 39.6 kJ.m^{-2} มีผลเสริมฤทธิ์กันในการรักษาคุณภาพและชะลอการเจริญเติบโตของเชื้อราในผลสับปะรดพันธุ์ภูแล

คำสำคัญ: น้ำไอออไนซ์ การฉายรังสี การฆ่าเชื้อโดยไม่ใช้ความร้อน

Abstract

The aims of this work were to determine the effect of acidic electrolyzed water (AEW) and UV-C on reducing the surface mould severity in 'Phulae' pineapple and investigate fruit quality changes due to the treatments. The AEW treatment was given as dipping the fruit for 10 min. The UV-C treatments were applied as placing the fruit inside an UV-C chamber where the intensity of the UV-C lamp had around 80 W.m^{-2}, and the time taken were either 2.75 min (13.2 kJ.m^{-2}) or 8.25 min (39.6 kJ.m^{-2}). Treatments were applied as AEW 300 ppm, UV-C 13.2 kJ.m^{-2}, UV-C 39.6 kJ.m^{-2}, AEW 300 ppm + UV-C 13.2 kJ.m^{-2} and AEW 300 ppm + UV-C 39.6 kJ.m^{-2} to the de-crowned 'Phulae' pineapple and kept at 13±1 °C for 28 days, non-treated fruit was used as control treatment. The results found that the untreated sample had the highest mould severity of 76.67±1.67 % while AEW 300 ppm + UV-C 39.6 kJ.m^{-2} found the lowest as 49.17±5.83 % at 21-days of storage. The combination of AEW 300 ppm and UV-C 39.6 kJ.m^{-2} induced the total phenolic and total flavonoid content and the antioxidant activity (DPPH and FRAP). Combination of 300 ppm AEW dipping and 39.6 kJ.m^{-2} UV-C irradiation exhibited potential synergistic effects of quality retention and germicidal as an alternative from using fungicide.

Keywords: ionized water, irradiation, non-thermal sterilization

Introduction

Pineapple (*Ananas comosus* L.) cv. Phulae is a geographical indication (GI) cultivar originated from Chiang Rai Province, Thailand. Due to its distinctive quality of small size, thick skin and crispy texture, this pineapple has become popular for both domestic and export consumption (Kongsuwan *et al*. 2009). However,

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postharvest losses of 'Phulae' pineapple have been a problem for export due to growing of mould on the fruit surface during transportation. This study was to investigate into the effects of AEW and UV-C on controlling the surface mould on 'Phulae' pineapple, as well as to find out their effect on the fruit quality changed as the treatment were applied.

Materials and Methods

Pineapple cv. 'Phulae' with green mature and similar size was purchased from commercial farm in Chiang Rai. The stem was cut to leave 2 cm of peduncle on the fruit and the crown was already trimmed from the farm at a length of 3-4 cm. The AEW was generated from AQUECA-40 (Izumrud Research and Production Enterprise, Russia) device and diluted with RO water to obtain the concentration of available chlorine concentration (ACC) at 300 ppm. The fruit was dipped in AEW (300 ppm) for 10 min and air dry with a fan. Afterward, the fruits were put in the corrugated box and stored at 13 ℃ for 28 days. The UV-C irradiation chamber was home-made according to Safitri *et al*. (2015) with slightly modification. The intensity of UV-C irradiation had 8000 μW.cm^{-2}. The samples were radiated for 0 min (control), 2 min and 45 sec (13.2 kJ.m^{-2}), 8 min and 15 sec (39.6 kJ.m^{-2}). Then, the fruits were kept as AEW treatment. For the combination treatments, the sample was dipped in AEW first and followed by UV-C irradiation. Data were collected every 7 days until 28 days.

Mould severity was evaluated as described by Safari *et al*. (2020) with modification focus on the percentage of the de-crowned surface area in pineapple instead of the whole fruit surface.

For bioactive compounds and antioxidant activity, total phenolic compound content (TPC) was measured by using the Folin-Ciocalteu assay according to ISO 14502-1 (2005). Total flavonoid content (TFC) was determined by the aluminum chloride colorimeter method as described in Heimler *et al*. (2005). The antioxidant (DPPH free radical scavenging activity) capacities of sample were determined by following Khalaf *et al*. (2008). The ferric reducing antioxidant power (FRAP) was determined according to Benzie and Devaki (2017).

The data were analyzed with SPSS (version 20, Inc., USA). The significant tests of mean were separated by Tukey HSD test at $P<0.05$ and considered under completely randomized design (CRD). All of the data value were indicated as mean ± standard error (SE) and analyzed in triplicate.

Results and Discussions

1. Effect of the AEW and UV-C on mould severity in 'Phulae' pineapple

Significant variations were observed across different treatment groups and storage intervals (Figure 1). By Day 7, mould severity in the control group had increased to 25.83%, highlighting rapid mould progression in untreated fruits. In contrast, AEW treatment alone reduced mould severity dramatically to 6.67%, Chen *et al*. (2020) and Guentzel *et al*. (2010) were studied on longan and grapes, respectively, supported these findings, demonstrating the effectiveness of AEW in reducing mould severity on various fruits. While all treatments showed increasing mold over time, combining AEW with a higher UV-C dose (39.6 kJ.m²) offered the best defense by delaying the mold growth and keeping it lower than other treatments. Still, mould eventually increased in all groups, even with the best treatment reaching 69% by day 28. These findings suggest AEW and UV-C can effectively suppress mold initially, but long-term storage might require additional strategies.

2. Effects of AEW and UV-C treatments on bioactive compounds and antioxidant activity of the fruit

Pineapples showed distinct responses in pulp and peel TPC to AEW and UV-C treatments. Pulp TPC remained stable, while peel TPC increased significantly, especially with AEW and UV-C exposure (Figure 2).

This suggests AEW and UV-C induced oxidative stress to accumulate TPC in peel as a protective response of pineapple (Rohanie and Ayoub, 2012). AEW and UV-C treatments had contrasting effects on total flavonoid content (TFC) in different pineapple parts. In the pulp, TFC remained stable across all groups, while UV-C alone might cause a temporary dip followed by a rise, possibly due to stress response. Combining these treatments showed no clear impact on pulp TFC. Peel TFC, however, showed significant increases with all treatments, with AEW and UV-C being particularly effective. This suggested that they stimulated the flavonoid metabolism in the peel, with their combination having a synergistic effect as Nour *et al*. (2021) found that the combination of those treatment effects on the related phytochemicals such as TPC and total anthocyanin content. Overall, AEW and UV-C primarily influence peel flavonoids, potentially by boosting biosynthesis.

AEW and UV-C treatments exhibited differential effects on pineapple antioxidant activity by DPPH assay. Antioxidant activity in pulp remained relatively stable across all groups, suggesting minimal impact on endogenous antioxidant machinery. Conversely, antioxidant activity in the peel displayed a significant and dose-dependent increase with all treatments, particularly in the combined AEW+UV-C groups. This potentiates a synergistic interaction between these treatments, potentially upregulating antioxidant biosynthesis pathways within the peel tissue (Zhang *et al*., 2021). AEW (300 ppm) and UV-C treatments diverged in their impact on antioxidant activity in pineapple by FRAP assay. FRAP activity in pulp remained stable, suggesting minimal influence on endogenous antioxidants. Conversely, FRAP activity in the peel displayed a marked increase, surpassing pulp levels. All treatments, especially AEW+UV-C combined, significantly boosted antioxidant activity in the peel. This suggests these treatments primarily influence peel FRAP, potentially via upregulating biosynthesis pathways. Notably, the combined treatment displayed synergy, leading to the highest peel FRAP.

Summary

Combination of 300 ppm AEW and 39.6 $kJ.m^2$ UV-C found the least mould severity among the treatments at 21 days of storage. Interestingly, both treatments significantly increased beneficial compounds (TPC, TFC) and antioxidant activity (DPPH, FRAP), particularly in the peel. Overall, AEW and UV-C show promise for extending pineapple shelf life and quality.

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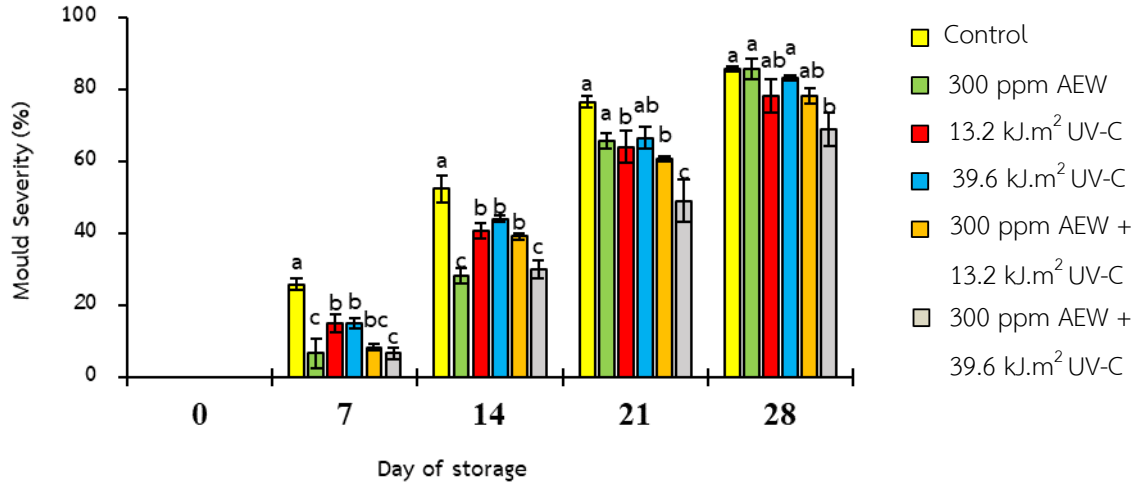

Figure 1 Mould severity in 'Phulae' pineapple during storage at 13 °C for 28 days. Each vertical bar represents mean ± SE (n=3). Different letters within the same column represent significance difference (P<0.05)

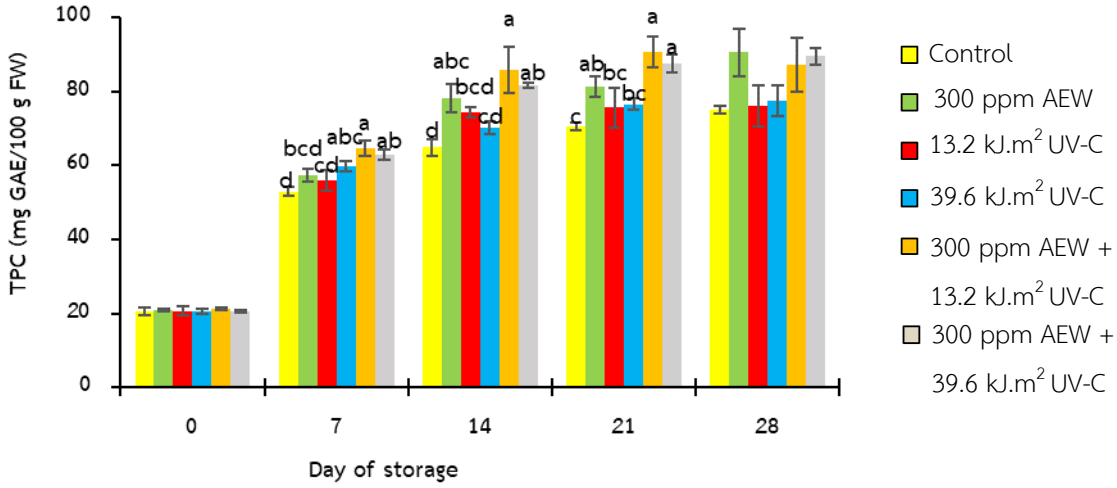

Figure 2 Effects of AEW and UV-C on TPC of 'Phulae' pineapple peel during storage at 13 °C for 28 days. Each vertical bar represents mean ± SE (n=3). Different letters represent significance difference (P<0.05)