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ผลของการฉายรังสียูวีซีก่อนและหลังการบรรจุแบบสุญญากาศต่อการเปลี่ยนแปลงคุณภาพระหว่างการเก็บรักษาและภายใต้สภาวะจำลองการขนส่งสับปะรดภูแลตัดแต่งพร้อมบริโภค

Effects of UV-C Irradiation before and after Vacuum Packaging on Quality Changes During Storage and under Simulated Transport Conditions for Fresh-cut 'Phulae' Pineapple

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บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อเปรียบเทียบผลของการฉายรังสียูวีซีก่อนและหลังต่อการเปลี่ยนแปลงคุณภาพของสับปะรดภูแลตัดแต่งพร้อมบริโภคและในระหว่างสภาวะจำลองการขนส่ง โดยการฉายรังสียูวีซี 2 ระดับ คือ 800 และ 1200 J/m^2 กับตัวอย่างทั้งก่อนหรือหลังบรรจุสุญญากาศ จากนั้นเก็บรักษาตัวอย่างที่อุณหภูมิ 5±1 องศาเซลเซียส จากการทดลองพบว่า ตัวอย่างที่ไม่ผ่านการฉายรังสียูวีซีมีปริมาณน้ำไหลออกจากเซลล์ (Juice leakage: JL) สูงสุดประมาณ 26.33±3.21 มิลลิตรต่อถุง สอดคล้องกับการลดลงของค่าความแน่นเนื้อ ตัวอย่างที่ผ่านการฉายรังสียูวีซีที่ความเข้มข้น 1200 J/m^2 ก่อนการบรรจุ มีปริมาณจุลินทรีย์ทั้งหมดน้อยที่สุด คือ 4.01 Log CFU/g จึงใช้สภาวะนี้ในการศึกษาการเปลี่ยนแปลงระหว่างการขนส่ง ซึ่งจำลองตามข้อมูลจากผู้ประกอบการในจงหวัดเชียงราย โดยเก็บตัวอย่างที่ได้รับการฉายรังสียูวีซีที่ 0–4 องศาเซลเซียส เป็นเวลา 24 ชั่วโมง จากนั้นย้ายตัวอย่างบรรจุในกล่องโฟมและเติมน้ำแข็งปิดฝากล่องและเก็บไว้ที่อุณหภูมิห้องเป็นเวลา 12 ชั่วโมง หลังจากนั้น ย้ายตัวอย่างไปเก็บที่ 10–15 องศาสเซลเซียส จำลองอุณหภูมิของการวางจำหน่าย ผลการทดลอง พบว่า เกิดก๊าซในถุงตัวอย่างที่ไม่ผ่านการฉายรังสียูวีซี (ชุดควบคุม) เมื่อเก็บรักษานาน 10 วัน และเกิดกลิ่นหมัก ซึ่งมีปริมาณจุลินทรีย์ทั้งหมดสูงกว่าตัวอย่างที่ได้รับรังสียูวีซี 2 Log CFU/g อย่างไรก็ตาม ตัวอย่างที่ผ่านการฉายรังสียูวิซียังอยู่ในสภาพการบรรจุสุญญากาศ และมีปริมาณจุลินทรีย์ทั้งหมด 4.74 Log CFU/g เมื่อเก็บรักษานาน 2 สัปดาห์ โดยการฉายรังสียูวีซีที่ 1200 J/m² ก่อนบรรจุสุญญากาศเป็นอีกหนึ่งวิธีทางเลือกที่สามารถรักษาคุณภาพสับปะรดภูแลตัดแต่งพร้อมบริโภคในระหว่างการขนส่งได้

คำสำคัญ ผลไม้ตัดแต่งพร้อมบริโภค อายุการเก็บรักษา ยูวีซี การบรรจุสุญญากาศ

Abstract

The objective of this work was to compare the effect of pre- and post-UV-C irradiation on the quality changes of fresh-cut 'Phulae' pineapple and after that during the simulated transport conditions. Two doses of UV-C radiation, including 800 and 1200 J/m² were applied to fresh-cut 'Phulae' pineapple before or after vacuum packing. The treated samples were then kept under 5±1°C. It was found that the untreated sample had a high amount of juice leakage (JL) of approximately 26.33± 3.21 mL/bag, along with a reduction in firmness. The dose of 1200 J/m^2 irradiated before packaging was chosen for simulating transportation due to its lowest total plate count (4.01 Log CFU/g). The transport condition was simulated according to the local fresh-cut company in Chiang Rai. The samples were kept at 0–4 °C for 24 hours, then loaded by pack in the foam box with ice and stored at ambient temperature for 12 hours. After that, samples were moved to 10–15 °C, imitating the shelf temperature. The results showed that after 10 days of storage, the sample without UV-C irradiation (control) contained escalated internal gas and provided fermented odors. The TPC was 2 Log CFU/g higher than the irradiated sample. However, the treated sample was found sound in the vacuum packing condition, and TPC was 4.74 Log CFU/g at 2 weeks of storage. Irradiating with UV-C at 1200 J/m² before vacuum packaging offered a trustworthy alternative for maintaining the sensory qualities of fresh-cut 'Phulae' pineapple during transportation.

Keywords: fresh-cut fruit, shelf life, UV-C, vacuum packing

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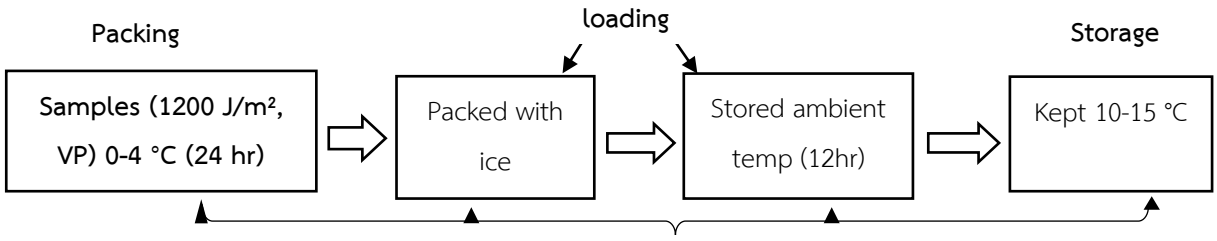
Introduction

'Phulae' pineapple is registered as a Geographical Indication (GI) of Chiang Rai, Thailand. With its unique characteristics, a fresh-cut 'Phuale' pineapple has become increasingly popular in domestic and overseas markets. Fresh-cut processing, on the other hand, faces challenges such as limited shelf life, browning incidence, and microbial spoilage during transportation. Quality changes during transportation and short shelf life are the main problems for fresh-cut 'Phulae' pineapple. UV-C irradiation is one of the most reliable techniques used in the fruit and vegetable industry to inhibit microbial spoilage. This study aimed to investigate the effects of UV-C irradiation before and after vacuum packaging on the microbiological control for extending the shelf life of 'Phulae' pineapple. The obtained results would provide guidelines to 'Phulae' pineapple postharvest operators for maintaining the quality and safety of the fresh-cut commodities.

Materials and Methods

1. Sample Preparation and UV-C treatments

Peeled 'Phulae' pineapples were obtained from the local company located in Chaing Rai province. The samples were vertically cut, soaked in 2% NaCl for 1 min with RO water and dried out of water. After drying out of the water, samples were exposed to UV-C radiation at 800 J/m2 and 1200 J/m2 (80, 120 sec) and then packaged with a vacuum package. As post UV-C treatment, the samples were packed with the vacuum package first, then exposed to UV-C radiation 800J/m² and 1200J/m² (102 sec, 127 sec). A control sample was vacuum-packed without UV-C treatment. All samples were thereafter stored at 5+1 °C, with 2 days of sampling for 14 days. The best condition of UV-C irradiation among treatments was selected to use the quality changes of the fresh-cut sample during transportation, which was conducted according to the local fresh-cut company in Chiang Rai. The condition during transportation was set as imitating the transportation from Chiang Rai to Bangkok as shown in the flowchart. Each of the steps was analyzed for quality until 14 days of storage (Figure 1).



▲ **Mean that Sampling was done for quality determination at each step until 14 days of storage.**

Figure 1 Quality determination of treated sample at each step under condition during imitating transportation

2. Determination of physical quality and chemical quality

The color of pineapple slices was measured with a colorimeter (CM-600d, Konica Minolta, Tokyo, Japan) for L*, a*, b*, and ΔE values. Juice leakage (JL) was measured according to the method of (Mohd Ali et al., 2022). Firmness was tested with a Texture Analyzer (TA. XT plus, UK) on 5 fruits per treatment by using a shearing test. Total soluble solids (TSS) were measured with a digital refractometer (Model: PR-a, ATAGO, Japan), titratable acidity (TA) with a Brix-Acidity meter (Model: PAL-Easy ACID F5, ATAGO, Japan) and pH with a pH meter (Binder, Scientific Promotion Co., Ltd).

3. Determination of bioactive compound and antioxidant activity

Vitamin C content was measured by titrating a sample with 2,6- dichlorophenol indophenol until a stable rose-pink color appeared according to AOAC (2000) method. DPPH radical scavenging activity was

assessed by mixing the sample with DPPH solution, then measuring absorbance to evaluate free radical scavenging activity (Khalaf *et al.*, 2008).

4. Determination of microbial count

Total plate count (TPC) analysis was conducted according to the **bacteriological analytical manual (BAM)** with results in log CFU/g after incubation at specific temperatures/periods.

5. Statistical analysis

The data was analyzed using analysis of variance (ANOVA) and Duncan's multiple range test at a 95% confidence level ($p < 0.05$). Statistical analyses were conducted using IBM SPSS Statistics 26, with all results reported as means ± standard deviation (SD). Each test was performed in triplicate to ensure accuracy.

Results and discussions

In the control sample, it was observed that there was a slight increase in juice leakage (JL) during storage, from 0 mL to 26.33±3.21 mL per bag. According to Figure 2, samples with UV-C treatment had significantly lower JL compared to the control group throughout storage period. The JL value remained below 10 mL for most of the storage period, with a slight increase upon 2 weeks. On the other hand, JL was significantly decreased by UV-C treatment (800 J/m² and 1200 J/m²) both before and after vacuum packing. This decrease in JL can be resulted from the UV-C's preservation effects, which could support cellular integrity and reduce the deterioration of tissue structure that causes JL (Huang *et al.*, 2017). The amount of JL was related to the reduction of the firmness. However, the combined benefits of vacuum packaging and high UV-C dosage exposure, 1200J/m² before and after treatment showed the best results, maintaining the highest firmness values. Other studies support these findings, showing that vacuum packaging considerably extends the shelf life and quality of stored goods by limiting microbial development and retaining the food's texture and firmness. (Domínguez *et al.,* 2021; Manzocco *et al.,* 2011; Mohd Ali *et al.,* 2022). No significant differences among the treatments were observed in color (L*, a*, b*) and vitamin C during storage. (Data not shown).

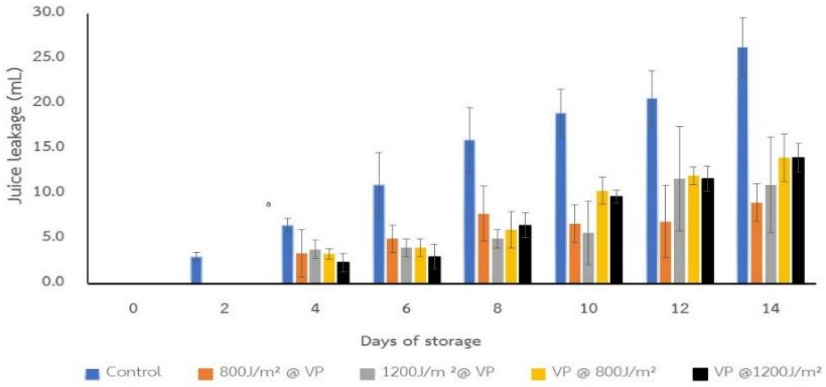


Figure 2 Juice leakage (mL) in fresh-cut 'Phuale' pineapple during storage at 5 ±1°C for 14 days

For microbial quality, after 14 days of storage, the higher dosage of UV-C treatment (1200 J/m²) before packing resulted in the lowest count among the treatments 4.10 Log CFU/g, which was below the National Department of Medical Sciences' microbial count safety level. Thus, to evaluate simulated transportation, a UV-C treatment of 1200J/m² was used before packing.

The TPC value of the control sample (without UV-C treatment) exceeded safety standards after 10 days. The TPC was 2 Log CFU/g higher than the irradiated sample. Moreover, the control sample had gas inside the package, and a fermented odor was observed. Li MeiLin *et al., 2019* reported that the fermentation of the sample was in relationship with the increasing amount of the microbial count at higher temperatures.

However, the treated sample was still under the safety level reaching 4.74 Log CFU/g at 14 days of storage (Table 1). The treated sample, on the other hand, was still in the vacuum packing condition and the quality of the fresh-cut fruits remained at an acceptable level. From the result, 0-4°C was recommended to store the fresh-cut 'Phuale' pineapple and other research suggested that temperature can influence microbial growth, with 5°C being the national safety threshold (Agüero *et al*., 2016; Domínguez *et al.*, 2021). Under simulated transportation conditions, TA, TSS and pH in the control group decreased in the range of 1.22 - 0.65 %, 15.03 - 9.43 Brix°, and 4.04-2.13 at each step of different storage temperatures. The control group of pH decreased more quickly after shifting from ice to 10-15°C, likely due to increased microbial activity or enzymatic processes. According to the pH data, the fermentation process started after one week of storage time.

Table 1 Total plate count (Log CFU/g) in fresh-cut 'Phulae' pineapple during simulated transportation.

Treatment	0-4 °C Ice packed	10-15 °C						
	0	2	4	6	8	10	12	14
Control	2.59±0.11a	3.18±0.04a	3.29±0.33a	4.19±0.49a	4.55±0.34a	5.33±0.02a	> STD	>STD
1200J/m², VP	2.19±0.06a	2.75±0.02a	3.03±0.31a	3.69±0.53b	3.58±0.08b	3.72±0.16b	4.01±0.10	4.74±0.50

Different letters within column showed differences at P<0.05. STD means standard level of TPC.

Conclusions

UV-C radiation effectively prevented a decrease in firmness, resulting in lower juice leakage. UV-C application with dosage of 1200J/m²UV-C performed before vacuum packing was recommended to preserve quality throughout storage at 5±1°C. During simulated transportation, the application of UV-C treatment had the potential to extend the shelf life of fresh-cut 'Phulae' pineapple by up to 14 days.

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