

Different methods of ethephon treatment on cacao (*Theobroma cacao* L.) pod ripening

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Abstract

Artificial ripening, using ethephon, has been employed by commercial fruit growers to take advantage of current prices in the market. However, there is no information on the effects of the different methods of ethephon treatment on cacao. This study aimed to evaluate the effects of different degreening methods (swabbing and soaking) using ethephon, on the ripening of 'BR 25' cacao pods harvested at the physiologically mature but unripe stage, in a completely randomized design. The response of three cacao cultivars (BR 25, UF 18, and W10) to 2500 ppm ethephon soaking treatment was also determined. The study revealed that both degreening methods resulted in a comparable ripening of 'BR 25' cacao pods. The 'BR 25' cacao pods subjected to the swabbing method retained higher pod weight at 3, 6, and 7 days after treatment (DAT) compared to those pods in the soaking method. Furthermore, TSS, TA, and TSS/TA of 'BR 25' cacao pulp juice from pods subjected to different degreening methods did not vary significantly. However, the 2500 ppm ethephon applied as a soaking treatment did not ripen the 'UF 18' and 'W10' cacao pods. Burning of the peel was observed in 'UF 18' cacao pods in response to ethephon treatment. These findings suggest that 'BR 25' cacao will ripen in response to ethephon treatment using the swabbing and soaking methods. Lastly, varietal differences exist among cacao cultivars in response to ethephon as a degreening treatment.

1. Introduction

Ethephon contains the stress hormone ethylene. Ethylene biosynthesis is prevented to prolong the shelf-life of most perishable crops (Kleiber *et al.*, 2018; Ku *et al.*, 2019; Moulai *et al.*, 2021; Sohail *et al.*, 2021; Supa *et al.*, 2024). However, nowadays, ethephon is being commercially applied to synchronize ripening, improve quality, and improve the visual appearance, and marketability of perishable fruit crops (Zhang and Zhou, 2019; Chowdhury *et al.*, 2020; Sapkota *et al.*, 2021; Cocco *et al.*, 2022). For instance, ethephon is used to ripen perishable fruits such as banana (Zenebe *et al.*, 2015; Maduwanthi and Marapana, 2019; Timilsina and Shrestha, 2022), pear (Dhillon and Mahajan, 2011), carambola (Le and Pham, 2018), citrus (Morales *et al.*, 2020), avocado (Rosas-Flores *et al.*, 2020), and mango (Nair and Singh, 2003; Lacap *et al.*, 2023).

In our previous work (Valleser and Valleser, 2025), we reported that 2500 ppm ethephon concentration hastened the ripening of 'BR 25' cacao pods. The cacao

pods were harvested at the physiologically mature but unripe stage (BBCH 79 according to Niemenak *et al.*, 2010). Through a cotton ball, the ethephon solution was swabbed onto the fresh wound of the cacao peduncle (Valleser and Valleser, 2025). However, this procedure is tedious especially when applied on a commercial scale. Thus, a degreening method that will save time and labor costs is advantageous.

In other perishable crops such as carambola, instead of the swabbing method, Le *et al.* (2018) soaked the fruits in varying concentrations of ethephon to ripen. Accordingly, Le *et al.* (2018) reported that the 1500 ppm ethephon treatment resulted in a better peel color appearance of the carambola. In contrast, higher doses of ethephon are detrimental and cause injury to the peel of Clementine and Shamouti oranges aside from the delay in ripening (Fuchs and Cohen, 1969).

This study was conducted to compare and evaluate the effects of different degreening methods (swabbing

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and soaking techniques), on the ripening of 'BR 25' cacao pods harvested at the BBCH 79 stage. The effects of 2500 ppm ethephon treatment using the soaking method in three cacao cultivars (BR 25, UF 18, and W10) were also assessed.

2. Materials and methods

2.1 Place and time of the study

This study was conducted at Lantapan, Bukidnon, Philippines. Cacao (cv. BR 25, UF 18, and W10) pods at BBCH 79 stage (Niemenak *et al.*, 2010) were harvested from a cacao farm located at Bugcaon, Lantapan, Bukidnon on August 5, 2023.

2.2 Experiment design and treatments

The experiment was arranged in a completely randomized design (CRD) with two treatments (swabbing and soaking) and fifteen replications. Each 'BR 25' cacao pod corresponds to an experimental unit. The 2500 ppm concentration of ethephon was prepared by mixing 5.2083 mL of Ethrel (48% ethephon) per 1 L of tap water. For the swabbing treatment, 1 cm of peduncle was retained in each 'BR 25' cacao pod using a sharp knife. The cotton ball dipped in 2500 ppm ethephon was then swabbed onto the fresh wound of the cacao peduncle as shown in Figure 1a. For the soaking treatment, cacao pods were soaked in a solution containing 2500 ppm ethephon (Figure 1b) for 1 min. After ethephon treatment, cacao pods were stored under ambient conditions. Observations on ripening were done until 7 days after treatment (DAT).



Figure 1. Swabbing (A) and soaking (B) methods of degreening using ethephon that served as treatments of the study.

For the cultivars, UF 18 and W10, the harvested pods were just soaked in 2500 ppm ethephon solution for 1 min due to the limited pod sample in the field during the conduct of this study.

2.3 Data gathered

The following data were gathered: a) number of days to ripening- this was determined when 50% of the cacao pods reached shell color index 3; b) shell color rating- this was determined using the shell color rating index for 'EET8' cacao as suggested by García-Muñoz *et al.* (2021); c) pod weight- this parameter was determined using the equation: Pod weight retention (%) = [(initial pod weight - pod weight after treatment)/initial pod

weight]*100; d) total soluble solids (TSS) - the TSS was measured using an Atago handheld refractometer [Organization for Economic Cooperation and Development (OECD), 2018]; e) titratable acidity (TA) - the TA measured in this study is the citric acid. Pulp juice (5 mL) from cacao was extracted and placed inside a beaker, and two drops of phenolphthalein solution were added. Titration then follows by adding a basic solution (0.1 N sodium hydroxide, NaOH) to the fruit juice until the color turns light red (OECD, 2018). The equation was then used to determine the TA (%): $TA = [\text{volume (mL) of NaOH added} \times 0.1 \text{ (NaOH concentration)} \times 0.064 \times 100] \div 5 \text{ mL}$; f) TSS/TA- this was determined using the formula: $TSS \div TA$ (OECD, 2018).

2.4 Statistical analysis

Data gathered were subjected to analysis of variance using the Statistical Analysis for Agricultural Research (STAR 2.0.1) software (<http://bbi.irri.org/products>). Significant differences between treatment means were separated using the Least Significance Difference (LSD) test.

3. Results

3.1 Ripening of cacao pods in response to degreening methods

The cacao pod shell color rating across days after treatment between the degreening techniques used in this present study (Figure 2) was not significant. It was also notable that the 'BR 25' cacao pods subjected to swabbing and soaking degreening methods continued to ripen as exhibited by the changes in peel color (Figure 3) and increasing shell color rating over time (Figure 2). For the 'UF 18' and 'W10' cacao, ripening as exhibited by the changes in peel color was not observed (Figure 4) until 10 days after soaking the pods in 2500 ppm ethephon solution.

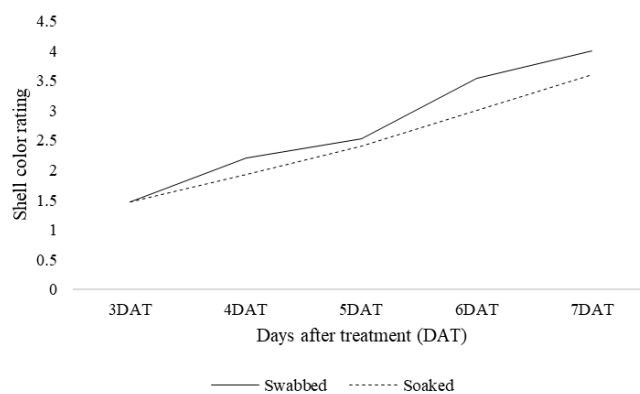


Figure 2. Shell color of 'BR 25' cacao pods in response to degreening methods. Data show no significant difference at 0.05 level via the LSD test.

In terms of days to cacao pod ripening, the difference was only 0.5 days to 'BR 25' cacao pod

ripening between the two degreening methods employed (Figure 5). Based on the analysis of variance, these figures were statistically comparable.

3.3 Cacao pulp total soluble solids, titratable acidity and total soluble solids/titratable acidity in response to degreening methods

The different degreening methods had comparable effects on the pulp juice quality (TSS, TA, TSS/TA) of cacao at the ripe stage (Table 1).

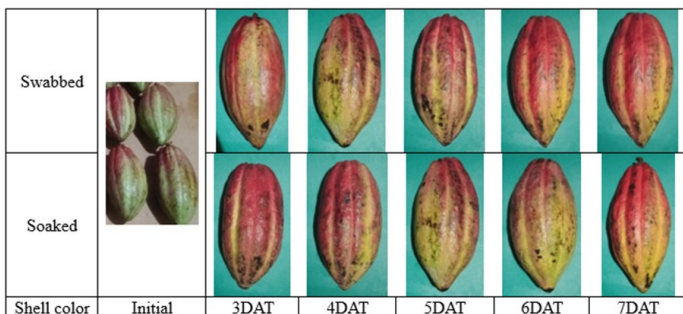


Figure 3. Changes in shell color of 'BR 25' cacao pods subjected to different degreening techniques.



Figure 4. Pods of UF 18 (left) and W10 (right) cacao cultivars in response to 2500 ethephon soaking treatment (picture was taken 9 days after treatment).

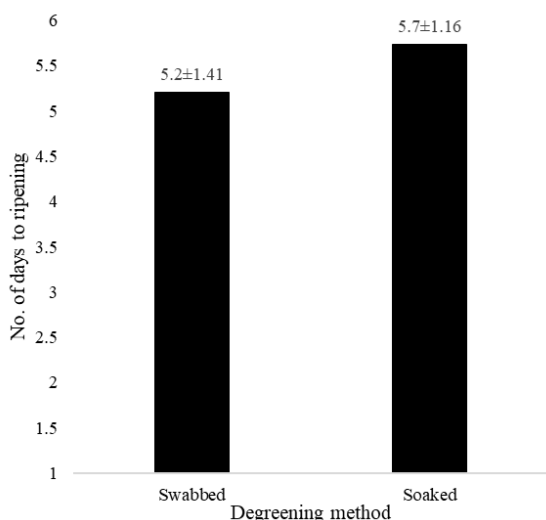


Figure 5. Number of days to ripening of 'BR 25' cacao pods in response to degreening methods. Data show no significant difference at 0.05 level via the LSD test.

3.2 Effects of degreening methods on the moisture content of cacao pods

Reduction of pod weight was exhibited by cacao pods after treatment with 2500 ppm ethephon treatment using different methods of degreening (Figure 6). Higher pod weight loss across periods after treatment was notable in cacao pods subjected to the soaking method. Significant differences in terms of pod weight were observed at 3, 6, and 7 DAT, of which cacao pods in the swabbing treatment retained pod weight more than those pods subjected to the soaking method of degreening.

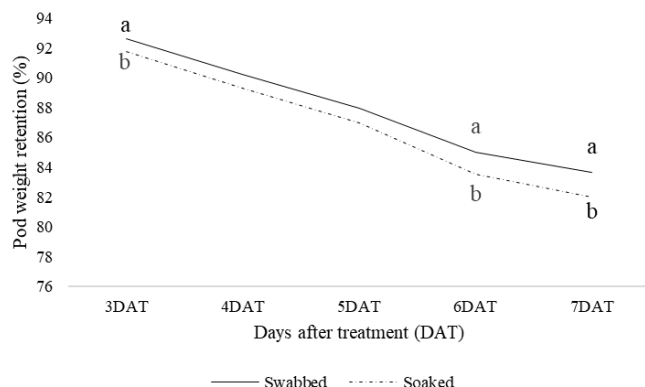


Figure 6. Pod weight retention of 'BR 25' cacao pods in response to degreening methods. Treatment means within days after treatment with different notations are significantly different at 0.05 level via the LSD test.

Table 1. Pulp juice quality of 'BR 25' cacao in response to degreening methods.

Degreening method	Pulp juice quality		
	TSS	TA	TSS/TA
Swabbed	11.86±2.11	0.83±0.15	14.42±2.46
Soaked	10.62±1.99	0.82±0.17	13.10±2.59
cv (%)	18.23	18.99	18.32
Significance	ns	ns	ns

ns: treatment means within column are not significantly different at 0.05 level LSD test

4. Discussion

Our results in this present investigation conformed to our previous report (Valleser and Valleser, 2025) that ethephon at 2500 ppm can hasten the ripening of 'BR 25' cacao. Moreover, our findings in this present study revealed that the effects of swabbing and soaking methods were comparable in terms of the changes in cacao pod shell color rating after treatment.

To ripen fruits such as bananas, ethephon solution is swabbed onto the fresh wound of the crown. Ethephon at higher doses will cause burning injury to the peel of the banana if applied as a soaking treatment. In this study, the higher dose of ethephon (2500 ppm) did not cause burning on the peel of the 'BR 25' cacao pod as shown in Figure 3. Thus, the method can be used in degreening 'BR 25' cacao pods. However, the 2500 ethephon soaking treatment did not ripen the 'UF 18' and 'W10' cacao pods (Figure 4). This finding implies varietal differences of cacao in response to ethephon as a ripening treatment. Moreover, the ethephon treatment

resulted in the peel burning of 'UF 18' cacao pods (Figure 4). This observation corroborated with the report of Fuchs and Cohen (1969) that higher doses of ethephon resulted in rind burning to lemons and caused a delay in the degreening of oranges cv. Clementine and Shamouti.

Once harvested and detached from the tree, fruits continue to lose moisture, sugars and other compounds through the process of transpiration and respiration. This condition is accompanied by the reduction of mass. The ethylene, released by ethephon, increases the respiration of fruits and vegetables (Kays and Paull, 2004) which probably occurred in cacao pods as well in this present study. The 'BR 25' cacao pods in the soaking method received more volume of ethephon compared to those in the swabbing method although the same concentration was used. This can be explained by the fact that external parts of the pods in the soaking method were wetted with the ethephon solution, while only the peduncle of pods was applied with the degreening solution through swabbing. Thus, as a result, the cacao pods in the soaking method received more ethephon and had higher weight loss at 3, 6, and 7DAT than those in the swabbing method.

Further, it was observed that the TSS, TA, and TSS/TA values of pulp juice regardless of the degreening methods employed in this present study were different from our previous work (Valleser and Valleser, 2025). In this present study, the TSS and TSS/TA were lower and TA was higher compared to our previous report using the same concentration of ethephon. This could be attributed to the harvest season as well as the origin of the 'BR 25' cacao pods that we used as samples. In our previous report (Valleser and Valleser, 2025), we harvested cacao samples during the dry season. In this study, however, samples were harvested during the rainy season of which fruit TSS is usually lower (Bihon *et al.*, 2022). On the other hand, titratable acidity or TA is influenced by climate according to what has been reported by Dorey *et al.* (2016) which supports the findings of this present study.

5. Conclusion

The ripening of 'BR 25' cacao pods subjected to swabbing and soaking degreening methods were comparable. Weight retention was higher in 'BR 25' cacao pods subjected to the swabbing method at 3, 6, and 7 days after treatment (DAT) compared to those pods in the soaking method. Comparable TSS, TA, and TSS/TA values of 'BR 25' cacao pulp juice were notable from pods subjected to different degreening methods. Unlike the 'BR 25' cacao, the 'UF 18' and 'W10' cacao pods did not ripen in response to 2500 ethephon treatment. Moreover, the ethephon concentration caused burning

injury to the peel of 'UF 18' cacao pods implying that varietal differences exist among cacao cultivars in response to ethephon as degreening treatment. Nonetheless, swabbing and soaking degreening methods using ethephon can be used to hasten the ripening of 'BR 25' cacao pods.

Conflict of interest

The authors indicate no conflict of interest.

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