

## Original Paper

The Physical and Sensory Qualities of ‘Lakatan’ Banana (*Musa acuminata*) in Response to Different Natural Ripening AgentsKarl Fritze S. Sampiano<sup>1\*</sup>, April Jeanne E. Durban<sup>1</sup><sup>1</sup>Department of Agricultural Sciences, College of Agriculture and Related Sciences, University of Southeastern Philippines, Tagum-Mabini Campus, Mabini Unit, Davao de Oro, 8807, Philippines\*Corresponding Author: [kfssampiano@usep.edu.ph](mailto:kfssampiano@usep.edu.ph)

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**Abstract**—‘Lakatan’ banana is amongst the most important banana varieties in the Philippines. This variety of bananas is widely known and cultivated due to its good sensory qualities and potential for the export market. Locally, ‘Lakatan’ banana is ripened by retailers through the use of calcium carbide and/or ethephon. However, these ethylene-producing chemicals were reported to cause poisoning and alter the fruit's taste. This study is designed to investigate the effects of natural ripening agents such as plant leaves on the ripening qualities and sensory attributes of ‘Lakatan’ banana under room conditions. The result results revealed that *C. muconoides* and *F. septica* significantly induced faster ripening of banana as compared to other treatments. Additionally, the disease severity of ‘Lakatan’ banana was lower in both leaves as compared to other treatments. On the other hand, bananas treated with *C. muconoides*, *F. septica*, and *A. carambola* leaves were found to have a longer marketable days. In terms of sensory quality, fruits treated with *C. mucunoides*, *G. sepium*, and *A. carambola* leaves were found to have high sensory acceptability. The results have concluded that leaves of *C. muconoides*, *F. septica*, *G. sepium* and *A. carambola* have great potential in ripening climacteric fruits like bananas, and these leaves are good substitutes for chemical ripening agents. The research highlights the need for further studies on the biological sources of ethylene to understand its advantages, including its limitations.

**Keywords**— calcium carbide, climacteric fruits, ethylene, ‘Lakatan’ banana, natural ripening agents

## I. INTRODUCTION

Banana (*Musa* spp.) is among the major crops in tropical and sub-tropical countries in the world and is widely consumed and cultivated on a large scale. This crop is one of the earliest cultivated fruit crops since the beginning of civilization. Bananas are widely available in Southeast Asian countries and are now cultivated in 130 countries both in tropical and subtropical regions globally [1]. Further, this crop was reported as the fourth largest food crop next to rice, corn, and wheat [2]. Annually, the world production of bananas was estimated to reach approximately 114 million metric tons, which were produced from over 5.6 million hectares of plantation [3].

In Philippines, the banana is considered the most important crop due to its production and commercial value. As one of the economically valuable crops of the country, banana production ranks first as it contributes to more than 100 million USD of the country's economy annually. Among the regions in the Philippines, Davao is considered the top producer of commercial bananas. Cavendish, Lakatan, and Saba are among the cultivated varieties of banana which account for 48, 30, and 11 % of the total production, respectively [4]. Lakatan banana is cultivated and harvested year-round, and its production in the year 2017 reached up to 910 metric tons in the Philippines [5]. Parts of this production are exported to other countries through air-conditioned containers, while others are distributed, ripened, and sold in the local markets.

As a climacteric fruit, banana is harvested in the maturely firm green stage of the crop [37]. Then, this fruit is subsequently ripened via artificial methods to establish its saleability and marketability while enhancing fruit-to-fruit uniformity. The ripening process of matured banana involves several physiological and biochemical processes that improve its taste, aroma, texture, flavor compounds, phenolic contents, and organic acids as it ripens [3]. In the Philippines, bananas and other climacteric fruits are generally ripened using calcium carbide (CaC<sub>2</sub>). This compound is commonly used as a ripening agent of climacteric fruits both by wholesalers and retailers in the Philippines at varying amounts per kilogram of fruit [6].

Commercially available calcium carbide in the form of pieces of rock-solid chunks contains harmful chemicals such as arsenic and phosphine. This compound was reported to contain 129.9 – 135.4 mg per kg phosphorus and 0.03 – 0.08 mg per kg arsenic traces [7]. These compounds can be emitted into the environment and could contaminate the treated fruits, potentially risky to human health [8]. When humans ingest these substances, they can get poisoned. The symptoms of arsenic and phosphorus toxicity include diarrhea, vomiting, burning sensation in the chest and abdomen, weakness, and difficulty talking and swallowing. Additionally, when these compounds are used in fruit ripening methods, they may potentially alter fruit flavor and sometimes induce ripening of

the peel while leaving the flesh raw [9]. Another commercial ripening agent used to treat climacteric fruits is the ethephon or chemically known as 2-chloroethyl phosphonic acid. This was reported to effectively ripen bananas because ethephon releases ethylene once it comes in contact with the cell sap at pH above 5.0, leading to fruit ripening [10]. What is more, this compound has been reported to cause eye irritation and skin allergy. Further, since ethephon is an organophosphate insecticide, it can cause neurotoxicity when ingested in large amounts.

With these health risks associated with those commercial ripening agents, a safer option is necessary for ripening climacteric fruits like bananas. The utilization of natural substances, such as plant leaves, has often been neglected as an important method of fruit ripening. Several plant species in the Philippines have been reported to contain higher amounts of ethylene, such as Madre de Cacao (*Gliricidia sepium*), star fruit (*Averrhoa carambola*), river tamarind (*Leucaena leucocephala*), and some weed species such as Calopo (*Calopogonium muconoides*), which affords promising biological activities in fruit ripening process [11]. The effects of *Jatropha curcas* and *Moringa oleifera* leaves on the physicochemical qualities of ripened bananas have been documented in Nigeria [12] and Ethiopia [13], respectively, and with significant results thereof. Meanwhile, *Carica papaya* leaves were used as the traditional ripening agent for women in Nigeria [14]. This study investigates the effects of the abovementioned plant leaves as an effective substitute to chemical ripening agents for Lakatan banana under room conditions. It specifically aims to determine what plant leaves can accelerate the ripening of 'Lakatan' banana without compromising its physical qualities and flavor.

## II. MATERIALS AND METHODS

### A. The Preparation of Plant Materials, Experimental Design, and Treatments

Commercially matured and unripe Lakatan bananas were harvested approximately 90 days after flower production [15] from the field in Carmen, Davao del Norte, Philippines on October, 2021. Three banana hands at the middle portion per bunch were selected, dehanded, clustered into 4-5 fingers per cluster, and then submerged into 200 uL/L NaOHl solutions for surface sterilization for about one minute (Fig. 1). The treatments of this study were; (T1) Madre de Cacao (*Gliricidia sepium*), (T2) Kamias (*Averrhoa balimbi*), (T3) Papaya (*Carica papaya*), (T4) Jatropha (*Jatropha. curcas*), (T5) Calopo (*Calopogonium mucunoides*), (T6) Ficus (*Ficus septica*), (T7) Moringa (*Moringa oleifera*), and control (T8). These leaves were collected in the same location where the bananas were harvested. The experiment was carried out in a Completely Randomized Design (CRD) replicated three times with five clusters per replication. The amounts of leaves were 10% (w/w) and calculated based on the total weight of bananas per experimental unit. Plant leaves were placed at the bottom center of a perforated bag (0.10mm thick with approximately 10 perforations measuring about 5mm in diameter) and the banana clusters were randomly assigned and subsequently placed inside the bag lined with newspaper. The banana clusters were covered with another sheet of newspaper and then secured in place with polypropylene twine and incubated for 48 hours under room conditions ( $26 \pm 2$  °C and 70-80 % relative humidity).



Fig. 1. The harvested (A), dehanded (B), and clustered 'Lakatan' banana fruits soaked in NaOHl (C) used in the study.

### B. Quality Evaluation

The quality of ripened banana fruits was assessed based on cumulative weight loss (%), firmness (N), peel color change, visual quality, the severity of disease, days to marketability, marketable days, shelf-life, and organoleptic attributes [36]. Cumulative weight loss was calculated as the difference between initial weight and final weight divided by the initial weight multiplied by 100 [16]. Fruit firmness was determined using a handheld penetrometer, and values were expressed as N [16]. Peel color change was assessed using a standard banana ripening scale (Table I) [17].

TABLE I. PEEL COLOR CHANGE RATING SCALE

Scale	Verbal Description
1	Green
2	Light green
3	Light green with yellow
4	Yellow with some green
5	Yellow with green at the ends
6	Full yellow
7	Yellow with brown spots

Visual quality was assessed using a visual quality rating scale (Table II) [16], while disease severity was measured using a scale presented in Table III [6]. Days to marketability refers to the number of days after harvest, after which the banana reaches a marketable stage of ripeness (i.e., peel color  $\geq 5$ , VQR  $\geq 6$ , and with  $\leq 5\%$  disease infection). Marketable days refer to the days in which the fruit can still be sold (i.e., the time when the fruit is deemed ripe up to the end of shelf life). The postharvest life on

the other hand refers to the period from which the bananas were harvested until the time beyond the limit of marketability [6].

TABLE II. VISUAL QUALITY RATING SCALE

Scale	Verbal Description
8-9	Clean with no defects
6-7	Clean with minor defects
4-5	Fair with moderate defects
3	Fair with major defects
1-2	Limit of edibility

TABLE III. DISEASE SEVERITY RATING SCALE

Scale	% Disease severity
1	0
2	1-5
3	6-10
4	11-25
5	>30

### C. Organoleptic Evaluation

The sensory evaluation was performed to assess the general acceptability of the fruit ripened with different bioethylene sources. Ten (10) randomly selected panelists were provided with the fully ripened Lakatan banana. They were asked to rate the fruit quality based on taste, aroma, mouthfeel, color, texture, and the overall acceptability of the ripened fruit. A five-point hedonic scale was used to measure each of these organoleptic parameters, which followed Sugri and Johnson [18].

### D. Data Analysis

Data collected in this experiment were put under Generalized Linear Model One-way Analysis of Variance to determine the significant differences among treatments followed by mean separation using Tukey's Honestly Significant Difference test. An alpha level of 0.05 was used as the threshold to confirm statistical significance. Data analyses were performed using Statistical Tool for Agricultural Research (STAR) software [19].

## III. RESULTS

### A. Peel Color Change

As indicated in the changed peel color, banana fruit treated with *C. muconoides* and *F. septica* leaves started to ripen 5 days after treatment (DAT). Two days thereafter (7 DAT), the banana fruits treated with these leaves showed full ripening (Fig. 2) and were confirmed to be statistically different from the control. Meanwhile, banana fruits treated with *G. sepium*, *A. carambola*, and *M. oleifera* leaves started to change their color at 7 DAT (Fig. 2) and significantly induced full at 10 DAT (Fig 3C). *C. papaya* and *J. curcas*, however, did not appear to affect the ripening of bananas since peel color change was found to be statistically similar to the control (Fig. 3C). The bananas treated with *C. papaya* and *J. curcas* leaves, on the other hand, were found completely ripe at 10-13 DAT, which was also similar to control.

### B. Cumulative Weight Loss

After 24 hours of treatment, the weight loss of fruits treated with *J. curcas* leaves was found the lowest of all the treatments, and it was significantly different from the control (Fig. 3A). Similarly, fruits treated with *C. muconoides* and *F. septica* leaves yielded lower weight loss but were found to be statistically similar to the other treatments. This trend in weight



Fig. 2. The appearance of 'Lakatan' bananas at 7 days after treatment with various natural ripening agents.

loss of 'Lakatan' banana treated with various natural ripening agents was identified throughout storage under room conditions. At 10 DAT, all bananas exhibited statistically comparable weight loss ranging from  $5.51 \pm 0.06\%$  to  $6.47 \pm 0.54\%$ .

### C. Fruit Firmness

Bananas treated with *C. muconoides* and *F. septica* leaves exhibited fruit softening at 5 DAT (Fig. 3B). Reduced firmness in bananas treated with *C. muconoides* and *F. septica* leaves was statistically comparable with the firmness recorded in bananas treated with *G. sepium* and *A. carambola* leaves. However, bananas treated with *J. curcas* leaves were still firm ( $30.67 \pm 1.20$  N) and found to be statistically similar to the control bananas ( $38 \pm 0.57$  N). All treated bananas showed a reduction of firmness throughout storage, which was a sign of ripening, except for the ones treated with *J. curcas* leaves and control that did not show any significant reduction of firmness until 10-13 DAT. At 16 DAT, all treatments were compared with each other in terms of fruit firmness.

### D. Visual Quality and Disease Severity

All bananas treated with various natural ripening agents showed excellent visual quality from 1 DAT until 5 DAT (Fig. 3D). The reduction of visual quality was noted at 7 DAT, wherein bananas treated with *J. curcas* and *G. sepium* leaves showed minor defects but were found to be statistically comparable with the other treatments. At 10 DAT, a significant

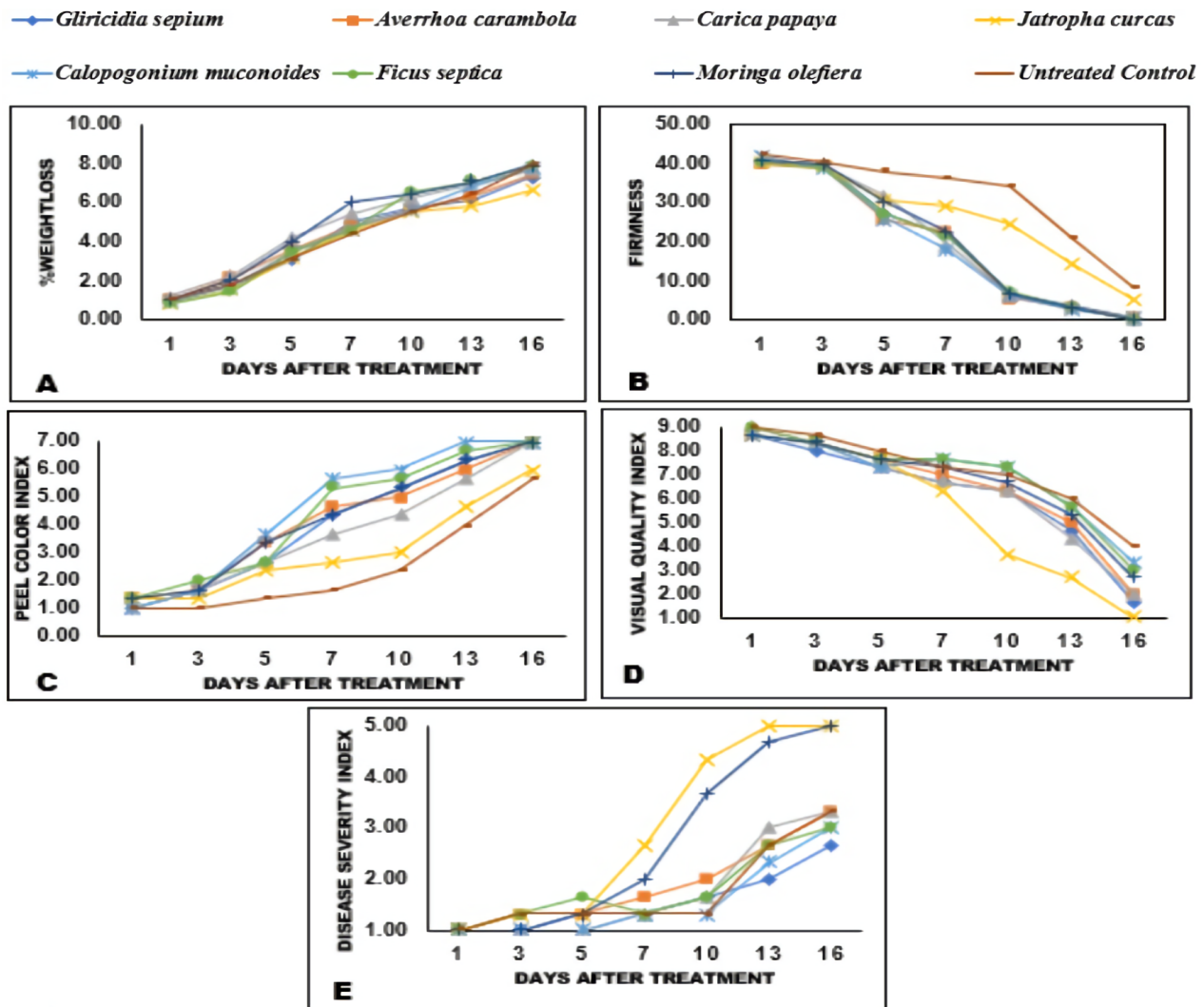


Fig. 3. Weight loss, firmness, peel color change, visual quality and disease severity of 'Lakatan' banana treated with various natural ripening agents.

reduction of visual quality was observed in bananas treated with *J. curcas* leaves, wherein major defects were recorded (rating of  $\leq 3$ ) in bananas. Nevertheless, all treatments showed minimal defects (rating of  $\geq 6-7$ ) under ambient conditions. On the other hand, the disease severity of 'Lakatan' banana as influenced by various natural ripening agents did not differ significantly from 1 DAT up to 7 DAT under ambient conditions (Fig. 3E). However, during 10-16 DAT, disease severity was significantly observed in bananas treated with *J. curcas* and *M. oleifera* leaves, which involved finger rot and anthracnose. Unexpectedly, the growth of white molds on the fingers was also recorded in bananas treated with *J. curcas* and *M. oleifera* leaves.

#### E. Marketability and Postharvest Life

'Lakatan' bananas treated with *C. muconoides* and *F. septica* leaves showed the shortest duration to reach the marketability stage (Fig. 4A). The number of days to attain the peel color of  $\geq 5$ , VQR  $\geq 6$ , and with  $\leq 5\%$  disease infection was  $6.67 \pm 0.32$  and  $7.33 \pm 0.33$  for fruits treated with *C. muconoides* and *F. septica* leaves, respectively. The slightly higher duration was recorded in bananas treated with *G. sepium* and *A.*

*carambola*, which was statistically comparable with the fruits treated with *F. septica* leaves. The longest duration to reach the marketability stage was observed in bananas treated with *J. curcas* leaves and those in control that ranged from  $12.33 \pm 0.67$  to  $12.67 \pm 0.33$  days. On the other hand, a longer duration of marketable days was observed in bananas treated with *C. muconoides*, *F. septica*, and *A. carambola* leaves which were par with those in control (Fig. 4B). Meanwhile, bananas in control had the longest postharvest life of all treatments (Fig. 4C) and were statistically comparable with those treated with *J. Curcas*.

#### F. Organoleptic Qualities

Among all treatments, bananas treated with *C. muconoides* leaves had the highest sensory qualities, which was statistically similar to those treated with *A. carambola*, *F. septica*, and *M. oleifera* leaves. In terms of aroma, bananas treated with *C. muconoides* leaves still gained the highest score, followed by those treated with *G. sepium* and *A. carambola*, all of which were comparable.

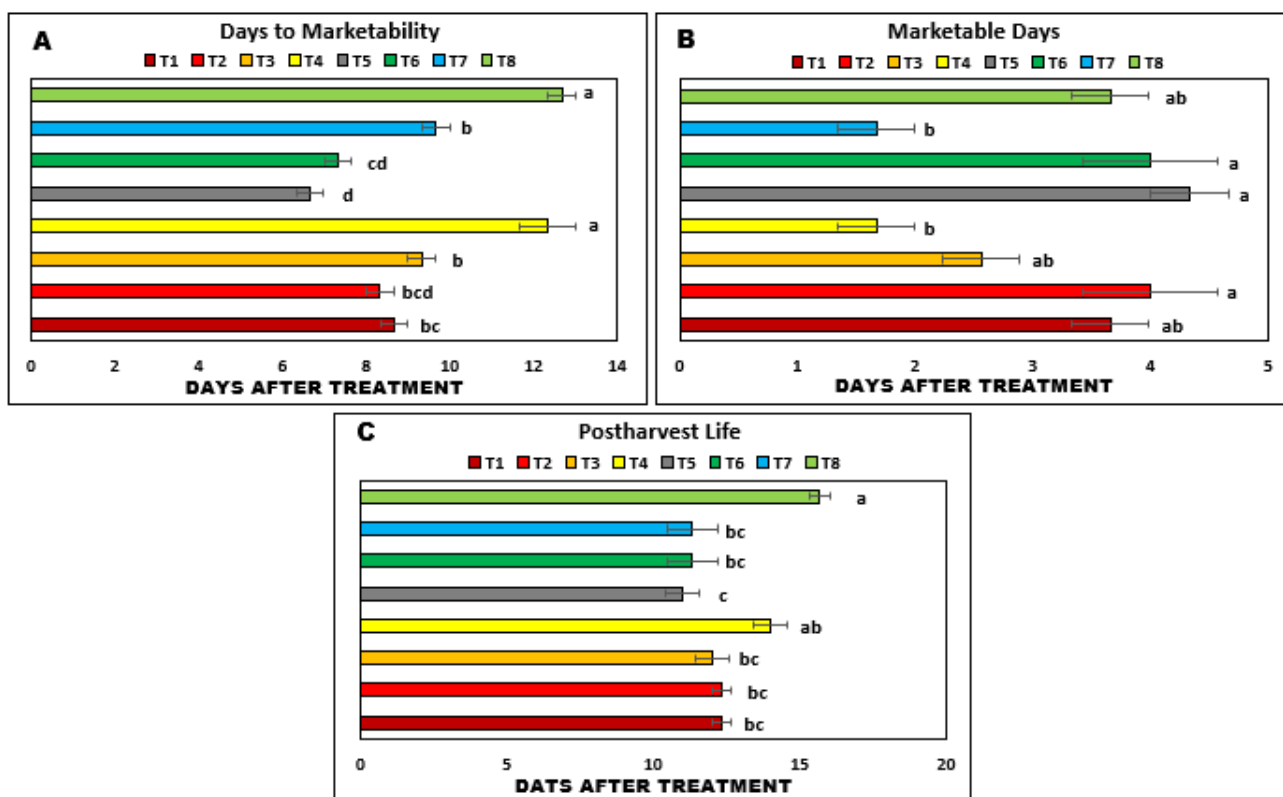


Fig. 4. Marketability and postharvest life of 'Lakatan' banana fruits as influenced by various natural ripening agents.

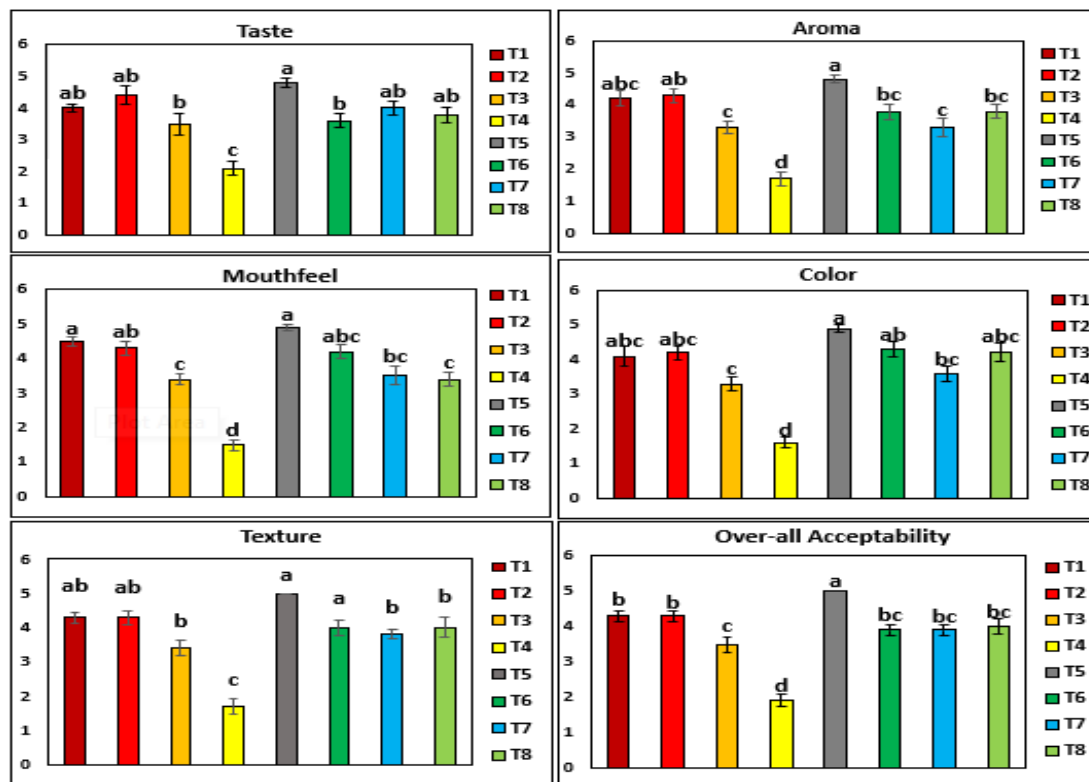


Fig. 5. Organoleptic qualities of 'Lakatan' banana fruits treated with various natural ripening agents.

The fact that bananas treated with *C. muconoides* leaves received the highest score was evident in all sensory parameters. It was further noted that 'Lakatan' bananas treated with *C. muconoides* leaves gained the highest score in terms of their overall acceptability. On the other hand, bananas treated with *J. curcas* leaves were less acceptable, which accounted for its consistently lowest scores across all sensory parameters.

#### IV. DISCUSSION

The life of any fruit is basically divided into three distinct stages, namely fruit set, fruit growth and development, and fruit ripening. Fruit ripening is the beginning of fruit deterioration which is a genetically inherent and highly coordinated process of transforming the fruit from its unripe to the ripe stage. This results in the production of highly attractive consumable fruit [20]. Fruit ripening is irreversible and can be characterized by a series of physical, physiological, biochemical, and sensory changes [21]. The primary reason associated with the complex process of ripening is  $C_2H_4$ , commonly termed ethylene, a gas found mainly in plants as phytohormone [22].

Banana, as a climacteric fruit, is considered ethylene-dependent during its ripening. Ethylene in any way affects fruit biochemical properties, which ultimately leads to physical and organoleptic changes. In this study, plant leaves were used as the source of ethylene to induce the ripening of 'Lakatan' banana. Results indicate that leaves of *C. muconoides* and *F. septica* significantly affect the firmness of the banana. It has been intensively reviewed that ethylene has an important role in fruit softening [23]. For instance, the firmness of tomato has decreased significantly with an increased concentration of ethephon, an ethylene releasing agent [24]. This is primarily due to the degradation of  $\alpha$ -1,4-linked galacturonic acid residues by the action of polygalacturonase enzyme [25]. With this, it is speculated through this study that the activity of polygalacturonase enzyme is significantly affected by the ethylene from the leaves of *C. muconoides*, *F. septica*, *G. sepium*, and *A. carambola* as indicated by the significant reduction of fruit firmness in 'Lakatan' banana.

Color development in fruits is a good indicator of fruit maturity and is directly associated with ripening [3]. In this study, bananas treated with *C. muconoides* and *F. septica* leaves rapidly changed their peel color as early as 7 days after treatment and were found to be statistically different from those in the control. Previous works in the literature reported that peel color change was observed in mango fruit treated with *G. sepium* and banana leaves 5 days after treatment [6]. Further, the acceleration of banana ripening was effectively achieved by *G. sepium* leaves [11]. Changes in peel color can be associated with the breakdown of chlorophyll pigments in the fruit by the chlorophyllase enzyme and, at the same time, unmasking of the carotenoid in the plastids resulting in the golden yellow color of the fruit [26, 27]. This study demonstrated that the ethylene produced by the plant leaves, such as in the case of *C. muconoides* and *F. Septica*, affected the activity of chlorophyllase enzyme while promoting the synthesis of carotenoid pigments and generating a fully yellow color.

However, this is not absolute in all treatments since other plant leaves such as *J. curcas*, and *C. papaya* delayed the peel color development of 'Lakatan' banana and was found to be similar to the control. This is probably because the ethylene production of those leaves was not that high to cause rapid degradation of chlorophyll pigments.

Regarding disease development in 'Lakatan' banana as influenced by various plant leaves, there was a varying degree of disease observed in the study. Bananas treated with *C. muconoides* and *F. septica* leaves had lower disease incidence. However, fruits treated with *J. curcas*, *C. papaya*, and *M. oleifera* leaves were noted to have higher disease incidence. The effects of ethylene on the development of post-harvest diseases in harvested fruits were still not clearly resolved. However, it was reported in the literature that an amount of ethylene in the storage atmosphere resulted in the development of *Botrytis cinerea* in strawberries [28]. This has been associated with the weakening of the dermal system of the fruits, which increased pathogen penetration [29]. On the contrary, ethylene has been demonstrated to improve the resistance of some harvested commodities against disease-causing microorganisms. For instance, tomato pre-treated with ethylene effectively inhibits the infection of *Botrytis cinerea* [30]. These authors suggest that the resistance may be due to the increase in peroxidase and polyphenol oxidase activities. The present study points out that the high ethylene production of *C. muconoides* and *F. septica* leaves as indicated by the rapid peel color change and fast reduction of firmness, increases the activity of peroxidase and polyphenol oxidase in 'Lakatan' banana. By extension, this results in lower disease incidence. The unexpected growth of molds in bananas treated with *J. curcas* and *M. oleifera* leaves was proposedly associated with the humidity inside the bag due to the rapid transpiration of leaves and fruits. The moisture released by the fruits and leaves was reported to favor the culture and development of the pathogen [31].

In connection with organoleptic attributes, ripening using ethephon, an ethylene-releasing compound, enhances the sensory and physicochemical qualities of bananas [32]. The general acceptability of the fruit, however, is influenced by the changes in its chemical contents, such as total soluble solids, pH, and titratable acidity. For instance, the TSS and pH in mango gradually increase as the fruit advances to the fully ripe stage. Meanwhile, titratable acidity was found to decrease in mango which made them highly palatable [33]. In the present study, there is high overall acceptability of 'Lakatan' bananas treated with various natural ripening agents, particularly those treated with *C. muconoides* and *F. septica* leaves. This result agreed with a previous report stating that the highest sensory acceptability was found in bananas treated with various natural ripening agents, such as apples, tomatoes, and pears [34]. It was also coherent with another study demonstrating that the aromatic compounds of bananas ripened naturally were significantly higher than those treated with ethylene [35]. The present findings, therefore, suggest that physicochemical properties of 'Lakatan' bananas are influenced by the ethylene produced by the plant leaves leading to its high organoleptic acceptability. On the contrary, bananas treated with *J. curcas*

leaves have lower acceptability. This is probably due to the increased disease severity found in *Jatropha*-treated bananas resulting in the reduction of sensory qualities and overall acceptability.

## V. CONCLUSION AND RECOMMENDATION

This experiment showed that various biological sources of ethylene, such as plant leaves, have the potential to effectively induce ripening in 'Lakatan' banana fruits in varying durations. In addition, particular leaves can effectively ripen bananas without compromising its physical and organoleptic qualities. *C. muconoides*, *F. septica*, *A. carambola*, and *G. sepium* induce faster ripening and therefore enhance the sensory qualities of 'Lakatan' bananas. Widely available for local markets, plant leaves can serve as effective ripening agents that are necessary for safer banana consumption, reduced costs of ripening inputs, and safer application. However, more efforts are highly encouraged to explore and unravel the potential of biological sources of ethylene in fruit ripening especially on the chemical aspects of the 'Lakatan' banana as well as on other climacteric fruits. Efforts in this field may positively affect the processing of climacteric fruits and the agri-food system as a whole.

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