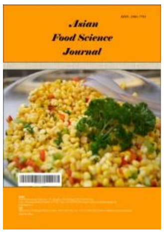

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Potential Application of Citrus Valencia Essential Oil (EO) on Three Mango Varieties and It Effects on the Quality Attributes of the Fruits

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

In today's world, synthetic preservatives, pesticides, fungicides, etc., misused are a call for concern, especially in the current health-conscious generation, whose consciousness to an extent have been due to the outbreak of many unknown and doubtful diseases. As such consumers' demands for as natural as possible or organic food have pushed food scientists, processors, preservatory, etc. to look for alternative natural sources especially plant botanicals. This study, therefore, extracted essential oil (EO) from orange peels (waste) of citrus Valencia fruit by a mechanical cold-press method. The essential oil was used for the treatment of three varieties of mango fruits (Broken, John, and Julie) and which were stored at room temperature. The fruits were then sampled and analyzed for quality attributes at four days intervals, from which the result of the control and treated mango fruits showed that citrus EO could extend the shelf-life of mango fruit by retaining most of the organoleptic properties in the unripped form. And in which 0.3 and 0.4 percent of the EO in carrier oil happens to show the best quality retention, a recommended percentage is used for further findings. However, it should be noted that the treated mango fruits did not ripen and that the immediate greenish outside of the peels due to the acidic nature of the extracted oil was also soft, but not the pulp of the fruits.

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Keywords: Natural preservatives; orange peels essential oil; mango fruits shelf-life extension.

1. INTRODUCTION

In the wake of many health-related challenges, with unknown or doubtful causes, the contemporary generation has been come very conscious especially of what they eat [1]. Meanwhile, in the light of the many complicated or enormous emanating types of cancers/cancerous cells, with many of which are said to be linked/associated mostly with exposure to synthetic chemical sources, consumers have become very conscious of the type of chemicals they take in as food, especially the type of preservative used in preserving the food [2,3].

Moreover, some researchers have proven synthetic food preservatives to be resistive to degradation or non-degradable, with the consequence of environmental impact effect as well as a cumulative side effect on the health of regular consumers of food products preserved with such chemicals [4,5]. And with the consequence of these synthetic chemicals is more pronounced in the case of fresh produce i.e., fruits and vegetables in which they are applied directly on the consumable portion as well as most at time few days to harvest or even after harvest.

In most of the abused use or excesses with the possibility of leading to the arrival of the product to the consumers with a higher level of these preservatives and the likelihood of lethality to the consumer. On the other hand, the emergence of mutants or synthetic food preservative resistive microbes and which is on the rise is demanding urgent alternatives [6]. These worries are today pushing food scientists, food technologists, and food preservatory to look for an alternative [7], because, despite the side effect of synthetic food preservatives, food preservation is a continuous fight against microbial spoilage with the consequence of rendering the food unsafe as such there is need to look for alternative and humane safe food preservatives [8], to continue the fight and to an extent guarantee food security.

Going through some works of literature following the trend of trying to mitigate the worriedness of consumers, health agencies, food preservatives regulatory agencies about synthetic food preservatives as well as farmers concerns of trying to conserve their hard end harvested produce, many researchers have already tried many extracted essential oils from different sources in preserving fresh produce such as tomatoes, papaya, mangoes, banana, etc. However, non-of these findings have a focus on the application of citrus essential oil as a potential freshly harvested green mango shelf-life extender. It is therefore in line with this gap that this finding did focus.

1.1 Objectives of finding

This study was done to evaluate the storage stability and quality indices of EOs treated three mango fruits varieties, as well as to evaluate the organoleptic properties of EOs treated mango fruits during storage.

2. MATERIALS AND METHODS

Study area: Benue state is one of the states in Nigeria and Makurdi is the state headquarter located along latitude 7.7337499 ^{0}N and longitude 8.52139 ^{0}E in the northern hemisphere.

Experimental site: The experiment was carried out at the chemistry laboratory and food chemistry laboratory all on the Benue State University campus. And all chemicals used were analytical grades.

2.1 Material

Plant material: The citrus Valencia orange was purchased from a well-managed Akperan-Orshi polytechnic orchard and transported to Makurdi where the essential oil was extracted. The three matured green mango varieties were obtained from the well-managed Akperan-Orshi polytechnic orchard in Gboko local government. It was then hand-harvested early in the morning to avoid field heat and was transported in caution crates to Makurdi where the experiment was carried out. Upon arrival in Makurdi respiratory as well as field heat was removed via running tap water over the fruits as shown in Fig. 1.

Preparation of fruits for treatment: Upon arrival, the fruits were rapidly cooled under running tap water to remove the field and/or respiratory heat which could facilitate deterioration. After the rapid cooling, the fruits were then washed with tap water to get rid of dust, dirt, and pesticides. After which the fruits were then grouped into 8 groups of 8 fruits each and in triplicates to give 24 fruits per treatment lot.

Experimental design: The research had essential oil as the one factor at different concentrations (0.2%, 0.4%, 0.6%, 0.8%, 1% 100%), and was laid out in a completely randomized design (CRD) with eight fruits per treatment and in triplicates giving twenty-four fruits per treatment lot [9]. With the various lots named as TT, for control, T1, T2, T3…T7 for treatment 1 to treatment 7.

Dilution of citrus Valencia essential oil: The citrus Valencia essential oil was diluted using a carrier oil, to obtain different concentrations for the different treatment lot and to get the concentration with the best preservative property as well as good quality maintenance attributes.

2.2 Methods

2.2.1 Treatment

The precooled washed, and grouped fruits were then treated with the different concentrations of the citrus Valencia essential oil, by fumigation using a sprayer. After treatment, it was then laid on a placement cartoon (as shown in Fig. 2 below) with the numbered position for the holding of the fruits throughout the storage period of sampling and analysis at four-day intervals.

Fig. 1. Removal of field heat under a running tap.

Fig. 2. The display of treated mango fruit on placement cartoon

2.2.2 Determination of physicochemical properties of citrus valencia (EO) treated and stored three mango fruits varieties

Firmness: Fruits randomly pick from each of the treatment lots on each analysis day, were examined for firmness using the non-destructive method with the aid of a durometer model HC 0.05. After sampling, the fruit was held on the left hand and the pointed (3mm) but the blunt end of the durometer was placed on it and a little force applied with the thumb, while the reading on the screen was taken.

Percentage weight change: With the aid of an electronic kitchen pan top scale model SF-400 capacity 10000 g/×1g/353oz×0.10oz, the weight of individual fruits after washing and air drying was recorded which save as the initial weight, and the fruits were randomly picked from each treatment lot for quality evaluation on each day of analysis and the four days interval was reweighed, using the same electronic balance. And the percentage weight losses were calculated using the formula in equation (1) [10].

$$Percentage\ weight\ change = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times \frac{100}{1} \quad (1)$$

Total soluble solids (TSS): With the aid of Bellingham + Stanely Abbe, 60/DR Code 10-99 made in UK N0 A 03074 model refractometer and of the AOAC (2005) recommended method of digital refractometer for total soluble solids. Fruits that were randomly picked from each lot for analysis, were pulp into juice using a mortar and a pestle without water addition, the juice was strained using muffin cloths to avoid fibers. A drop of the juice sample was then placed on the refractometer prism using a dropper and readings were taken in “degree Brix”, and the correction factor according to the temperature difference from the standard 20^0C added [11].

Titratable acidity: The juice from the randomly picked fruits prepared as for the total soluble solids was used for the titratable acidity determination. In which the juice was diluted with distilled water in the ratio of 1:10 i.e., 10 ml of juice were measured using a measuring cylinder into a conical flask and 100 ml of distilled water was measured and added unto it. Unto the mixture, three drops of Phenolphthalein were then added as an indicator. And the mixture was then titrated with 0.1 molarity sodium hydroxide (0.1 M NaOH) until the endpoint of pink color. Titratable acid of the mango juice present as malic acid was then calculated using equation (2).

$$Titratable\ Acidity = \frac{0.0064 \times \text{ml of 0.1N NAOH used}}{\text{volume of juice}} \times \frac{100}{1} \quad (2)$$

Where 0.0064 is the conversion factor for malic acid

pH: With the aid of the digital pH meter Hanna Instruments pHep HI96107 Pocket-Sized PH Meter, the pH of the randomly selected fruit juice for each day of analysis was determined using the standard method of digital pH meter determination. The pH meter was standardized using deionized solution until the pH reading in distill water was neutral. The pH meter was then inserted into the juice and the reading was recorded directly from the digital pH meter reading, with rinsing in distilled water after each sample reading before inserting into another sample.

Storage stability of citrus Valencia treated three mango varieties:

Temperature and Relative humidity: Temperature and relative humidity as two important factors in ensuring the storage stability of fruits such as mango fruit was determined on daily basis and for twenty days which analysis was carried out using an indoor/room digital alarm clock/humidity hydrometer.

Microbial load count: The estimation of the microbial load of the samples was done by the pour plate technique. In which with the aid of a sterile syringe, 1 ml of the samples of juice from the treatments lots was pullout using the syringe and transfer into 9 ml of sterile peptone water in screw-capped test tubes. From the first test-tube which saves as 10^{-1}, serial dilution was made up to the 10^{-6} dilution in other sterile capped test tubes with peptone water. Following the spread plate technique, 0.5 ml of the 10^{-2} and 10^{-4} of the serial dilution was pullout using a sterile syringe and poured into labeled sterile Petri dishes. A pressure cooker-cooked prepared culture media was then allowed to cool, after which about 20 ml was poured into the petri dish with the aliquots and swirl for proper mixing [12]. The plate was then incubated for 72 h at 37 ^{0}C and Colonies formed in the plates were manually counted with the actual number of cells estimated as colony-forming units (CFU/ml). And the cell plate count per milliliter(ml) per dilution was estimated using the total count equation (3)

$$Total\ count = \frac{\text{total number of colonies}}{\text{number of plate}} \times \frac{1}{dilution\ factor} \times \frac{1}{volume\ inoculated} cfu/ml \quad (3)$$

Percentage decay incidence and decay severity: Percentage decay incidence or deterioration and decay severity were assessed at the four days interval for twenty-day of analysis after treatment during the storage period of twenty-three days. The percentage decay incidence was evaluated by physical examination of the fruit for the appearance of decaying or infectious spot-on fruits.

Estimated shelf-life: The shelf-life of the three varieties of mango fruits for both the control and the citrus EOs treated fruits was estimated based on the numbers of days it took from harvested and experimental layup to when it starts losing physical quality attributes, till when it ran out of the acceptable quality attribute.

Organoleptic properties of citrus EOs treated mango fruits: The juice from the treated samples produced using a food blender was evaluated for its acceptability, on the last day of the analysis during the storage study by a panel of 15 non-trained panelists, which were regular mango eaters without any allergy. A juice sample from each lot was served to the panel of fifteen panelists. The panelists were then asked to evaluate the sensory quality of the samples as per the sensory score table. And the panel members were then snappily directed (or partially trained) on how to judge each sample based on appearance, flavor, juice texture, and overall acceptability, and indicate their degree of liking on a 9-point Hedonic Scale [13].

Statistical analysis: Data collected from the four-day interval analysis and for the total twenty-days of analysis were subjected to computer software for the analysis of variance (ANOVA). With Duncan Multiple Range Test for Significant Different calculated for the establishment of mean value at .05 or 5% significant level. A One-ANOVA Pos Hoc Ducan Multiple Range Test was also carried out to establish the difference between the different treatment lots. And all the analysis was done using Statistical Package for Social Sciences (SPSS) version 26.

3. RESULT AND DISCUSSIONS

Firmness: Fruits while on trees maintained firm and turgid structures, even though the catabolic process of respiration does also take place. This is because the catabolic process of respiration is counterbalanced by the anabolic process of photosynthesis. However, once the fruit is detached from the tree, the balance is interrupted. As the balance is interrupted, the breakdown comes in which involves especially pectin hydrolysis, through biochemical processes which usually lead to sweetening due to ripening [14]. However, the treated fruit for this finding did not ripen and as such, the loss of firmness was merely due to depolymerization and solubilization of cell wall components leading to loss of cell structure [15]. On the other hand, for the different lots, and the three varieties, the firmness change was more pronounced for the control, and in turn varies with the different treatment from T1-T7 as shown in Fig. 3 The treated fruits turn to maintain firmness more than the control, with a trend which did range from the lowest firmness in treatment one T1 to the highest firmness maintenance at treatment 4 of 0.6% essential oil. And after which the trend turns to decrease in firmness again. The maintenance is attributed to the interference of citrus essential oil with the second phase of ethylene production, whose production usually leads to a higher respiratory rate resulting in ripening. However, firmness turns to decrease for all treatments with the advancement of storage days.

Percentage weight change: Fruits e.g., mango are made up of mostly water on weight bases, respiration, and evapotranspiration which are continual physiological process in fruits that usually involves the loss of carbon in the form of carbon dioxide and water thereby resulting in weight loss [16]. The weight loss was greater in the control than citrus essential oil-treated fruits. And among the treated fruits, weight loss turns to decrease from treatment 1 to the lowest at treatment 3and 4 and in turn, slightly increases at treatment 5 to 7 than treatment 3 and 4, but still far lower than the control and it is as shown on Fig. 4. The minimal weight loss for the treated fruit is attributed to the citrus essential oil denaturing the respiratory cells of the peels as the green peels were charred. The treated fruits, however, witnessed weight loss with the advancement of storage days, which was in agreement with other findings [17,18].

Total soluble solids: The total soluble solid for both control and treated fruits, as well as for all the three varieties, were all showing an incremental tendency, though with a significantly lower value for the treated than the control. An increase in TSS could be attributed to the conversion of carbohydrates into simple sugars through normal complex mechanisms during storage [19,20]. The increase in the total soluble solid could also be attributed to an increase in the activity of enzymes responsible for the hydrolysis of starch to soluble sugars [21]. However, for this particular finding in which the fruits did not ripen due to the interference of essential oil with normal biochemical processes responsible for the process of ripening, for instance, such as interference with the phase two of ethylene production [22,15]. Meanwhile, phase two of ethylene production normally occurs after harvest in climacteric fruits and leads to ripening. But essential oil deed toasted the green peels, denatured the protein responsible for ethylene production and its transmission unto the pulp for ripening, the major source of TSS in this finding, therefore, was attributed only to enzymatic activities and cellular breakdown. And with the total soluble solid variation as shown in Fig. 5. A slight increase in TSS was, however, in agreement with that of other researchers [23,24].

pH: The pH or acidity of fruits is usually due to the presence of weak organic acids. However, these organic acids are also substrates for metabolic activities and as such since the various treatments lot fruits for this finding did not ripen, the increases in pH value or the decline in acidity in this finding was due to utilization of the initially present organic acids as respiratory substrates [21]. Meanwhile, the resistance in pH increase for the treated fruit was due to the non-ripening of the fruit. The variation in the pH with advancement in storage day is as shown in Fig. 6.

Titratable acidity: Since the treated fruits in this finding did not ripen as compared to control, the titratable acidity which was showing resistance to change as was also observed by [21], with fruits stored at a lower temperature than those at ambient temperature, could be attributed to essential oil inactivation of ethylene synthesis and the small gradual decrement with storage days would have been due probably to metabolism, respiration and other natural aging or breakdown processes [24]. The decrease in titratable acidity observed in the treated lots was, however, lower than that of the control just as was observed by Sefu et al, [9], in which the control showed a high reduction in titratable acidity value than cinnamon and ginger essential oil-treated fruits during the storage period. On the other hand, the reduction in TA was following other findings [25]. And the variation in TA with advancement in storage days is as shown on Fig. 7.

Microbial load counts: The microbial load count with advancement in storage days, from day zero, shows a different trend for the control and the treated lots. The count in turn shows an increase in count load with advancement in storage days for the control. Meanwhile, on the contrary, the treated lots show a decrement in count load with advancement in storage days. The lower microbial load count for the various treatment lots, when compared with the control, was probably due to the fungistatic nature of citrus essential oil [26,27]. The microbial load count is as shown in Table 1.

Disease incidence: The decay incident for the control could be physically examined as black spots which were likely due to anthracnose and other fungus attacks [28,29]. These spots in the control could be seen as well as when scraped showed signs of infection on the flesh (fruit pulp) and could equally be counted. However, for the treated fruit few spots which only happen to started appearing around the 9^{th} day after treatment could be seen, but, although the immediate thin layer of the peels was charred due to acidic (pH of ≈3.5) nature of extracted essential oil effect, when this spot was scraped off, the flesh underneath was still fresh and without infection sign. And which could be attributed to the fungistatic nature of citrus essential oil.

Estimated shelf-life: The shorter shelf-life for the control mango fruits could be due to a lack of resistivity to the anthracnose pathogenic fungus. Meanwhile, the prolonged extension in shelf-life for the treated fruits could be attributed to the fungistatic nature of the citrus essential oil as well as the modified micro-environment created by the oil coatings on the peels, which in turn interferes with many normal biochemical processes, hence, leading to extended shelf-life.

The decrease in

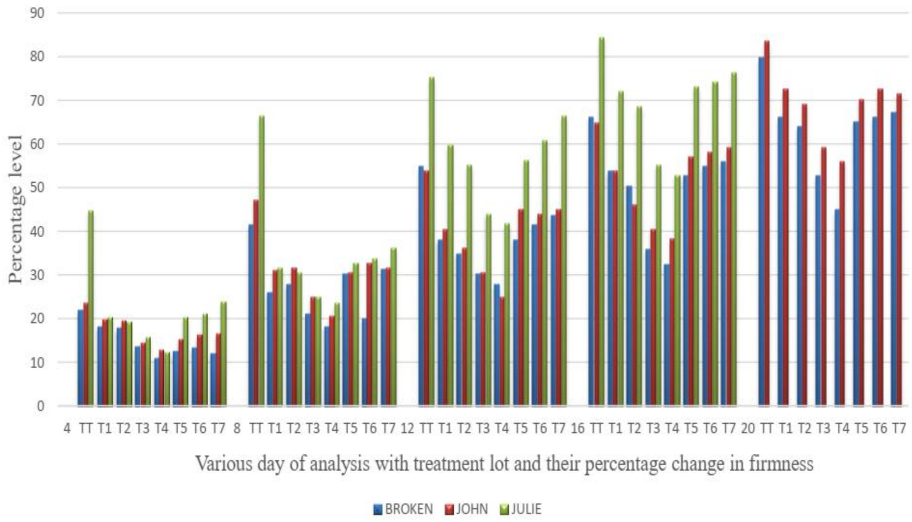

Fig. 3. Firmness change for the three mango varieties treated with Eos

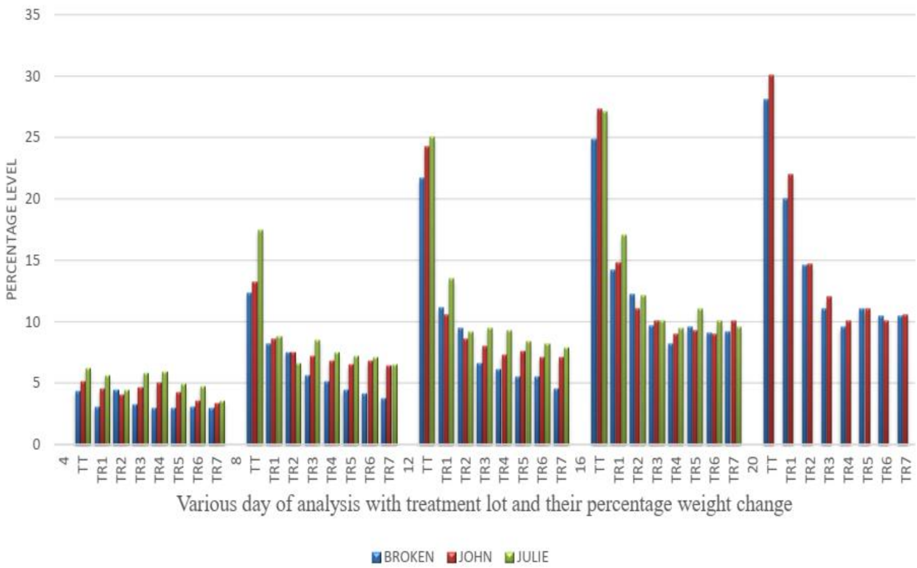

Fig. 4. Weight change for the three mango varieties treated with Eos

Sensory evaluation appearance: In terms of appearance, the SPSS analysis result shows that greater preference was given to; control (TT), followed by treatment one (TR1), (TR2), (TR3), (TR5), (TR6), (TR4), and (TR7) respectively. The preference of control could be attributed to the normal occurrence of the various biochemical processes for fruit ripening leading to the normal mango fruit appearance. Meanwhile, the discrepancies among the treated lots could be attributed to the influence of the extracted citrus essential oil, for as the concentration increases from treatment one to seven, the dislike in appearance also follows the same trend, but for treatment four in which there was some sort of a balance in synergy between the citrus essential oil and the carrier oil. The poor grading for the citrus EOs treated fruits was due to the retention of high unripe nature, as a result of non-production of ethylene for ripening and hence, poor edible quality [21].

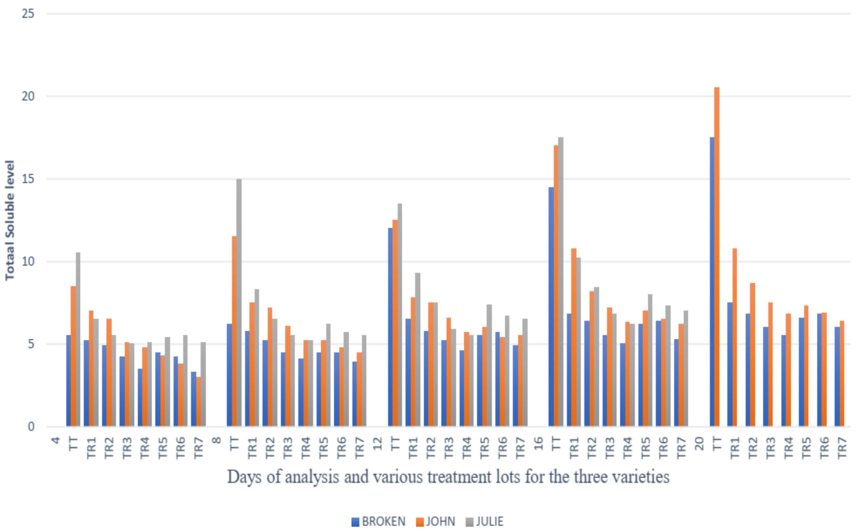

Fig. 5.Total soluble solid change for the three mango varieties treated with EOs

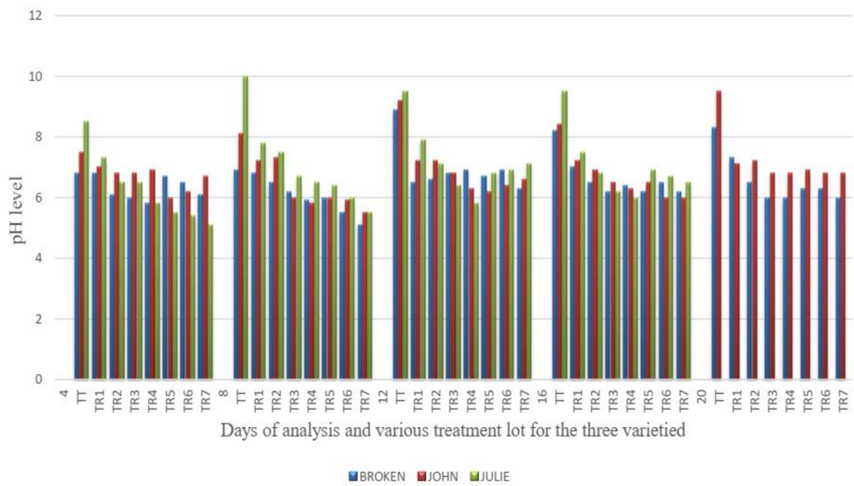

Fig. 6. pH change for the three mango varieties treated with EOs

Flavor: it did observe a similar trend as did appearance from control through treatment one to seven and which could be attributed to the inappropriate hydrolysis or breakdown of volatiles responsible for flavor as the essential oil did stop the normal functioning of cells on the peels, by interfering with normal biochemical reaction responsible for flavor production.

Texture: for the texture, a similar trend as for appearance and flavor was observed, but, for the fourth and sixth treatment interchanging position, this can be attributed to lack of proper hydrolysis of starch to monosaccharides which are responsible for juice texture.

Ripeness: Fruit ripening is a highly coordinated, genetically programmed, and irreversible phenomenon involving a series of physiological, biochemical, and organoleptic changes, due to the interference by the extracted citrus EOs treatments to one or more of these coordinated activities leading to non-ripening, greater preference was also given to the control, followed by one, two, three, six, five, four and seven treatments respectively in a decreased order of likeness.

Table 1. The microbial load count for the various days of analysis

Characteristics			Treatments							
		Days	TT	T1	T2	T3	T4	T5	T6	T7
		0	3.60×10^{3}	3.50×10^{3}	3.60×10^{3}	3.40×10^{3}	3.50×10^{3}	3.50×10^{2}	3.30×10^{3}	3.60×10^{3}
No of colonies (CFU/ml)		4	5.20×10^{3}	2.80×10^{3}	2.50×10^{3}	2.10×10^{3}	1.40×10^{3}	1.10×10^{3}	6.00×10^{2}	4.00×10^{2}
Shape of colonies	Circular	8	1.22×10^{4}	2.00×10^{3}	8.00×10^{2}	6.10×10^{2}	4.70×10^{2}	3.50×10^{2}	2.20×10^{2}	2.10×10^{2}
Edge of colonies	Flat	12	6.30×10^{4}	7.00×10^{2}	5.20×10^{2}	4.20×10^{2}	3.80×10^{2}	3.20×10^{2}	2.50×10^{2}	2.00×10^{2}
Color of colonies	Whitish	16	9.20×10^{4}	5.50×10^{2}	4.10×10^{2}	3.00×10^{2}	2.70×10^{2}	2.20×10^{2}	1.80×10^{2}	1.30×10^{2}
Surface of colonies	Rough	20	2.10×10^{5}	4.50×10^{2}	3.50×10^{2}	2.40×10^{2}	2.10×10^{2}	1.90×10^{2}	1.50×10^{2}	1.00×10^{2}

Table 2. Sensory evaluation result of the essential oil-treated three mango fruit varieties

Treatments	Sensory Attributes evaluated					General acceptability
	Appearance	Flavor	Taste	Texture	Ripeness	
TR7	$2.60^{d} \pm 1.45$	$2.47^{f} \pm 1.13$	$2.60^{e} \pm 1.12$	$2.40^{f} \pm 1.18$	$2.47^{d} \pm 0.92$	$2.73^{d} \pm 0.88$
TR4	$3.00^{d} \pm 0.65$	$2.80^{ef} \pm 0.68$	$2.73^{de} \pm 0.59$	$3.07^{de} \pm 0.59$	$2.67^{d} \pm 0.72$	$2.93^{d} \pm 0.80$
TR6	$3.07^{d} \pm 1.62$	$3.20^{de} \pm 0.94$	$3.00^{de} \pm 1.00$	$2.93^{ef} \pm 1.03$	$2.93^{d} \pm 1.22$	$3.00^{d} \pm 1.00$
TR5	$3.27^{d} \pm 0.88$	$3.27^{de} \pm 0.59$	$3.13^{de} \pm 0.52$	$3.20^{de} \pm 0.77$	$2.93^{d} \pm 0.96$	$3.13^{d} \pm 0.92$
TR3	$3.40^{d} \pm 0.63$	$3.40^{d} \pm 0.63$	$3.33^{d} \pm 0.62$	$3.60^{d} \pm 0.51$	$3.13^{d} \pm 0.74$	$3.40^{d} \pm 0.74$
TR2	$4.93^{c} \pm 0.88$	$5.13^{c} \pm 0.74$	$4.80^{c} \pm 1.08$	$5.47^{c} \pm 0.92$	$4.80^{c} \pm 0.86$	$5.07^{c} \pm 0.96$
TR1	$6.27^{b} \pm 1.16$	$6.27^{b} \pm 0.70$	$6.27^{b} \pm 1.16$	$6.33^{b} \pm 0.82$	$6.07^{b} \pm 1.10$	$6.07^{b} \pm 0.88$
TT	$8.33^{a} \pm 0.82$	$8.33^{a} \pm 0.49$	$8.13^{a} \pm 0.52$	$8.33^{a} \pm 0.49$	$8.53^{a} \pm 0.52$	$8.07^{a} \pm 0.70$

Mean, ($\bar{x}$) ± standard deviation (std) followed by different superscripts in the same column for the different sensory attributes are significantly different (p<.05) by Duncan's multiple range test.

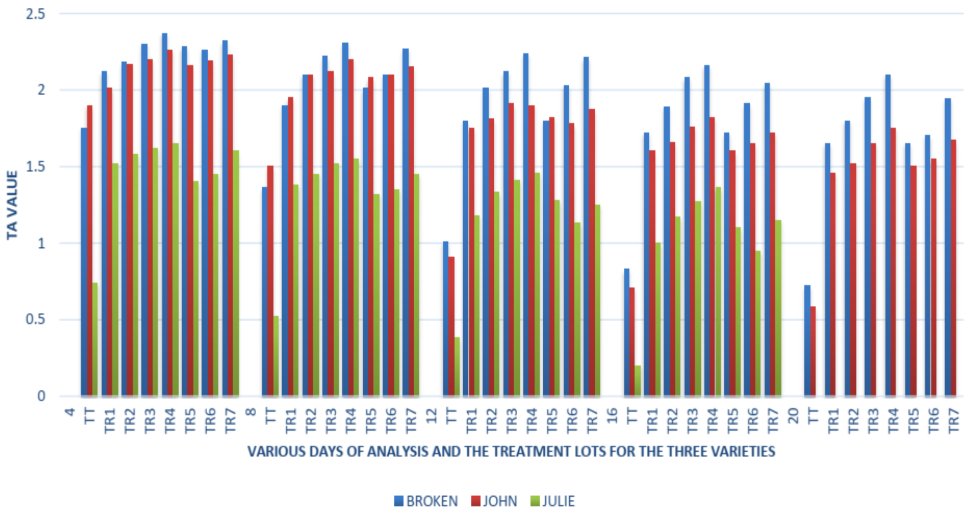

Fig. 7. Titratable Acidity change for the three mango varieties treated with EOs.

General acceptability: for the general acceptability the control was ranked first, followed by treatment one, two, three, five, six, four, and seven and with their corresponding ranking according to the hedonic scale standing for Like very much, Like moderately, Like slightly, Neither like nor a dislike, Dislike slightly, Dislike moderately respectively and as summarized in Table 2. From the SPSS analysis result, just as the result of the other analyzed physicochemical parameter, it can be seen that citrus Valencia essential oil-treated mango fruits did retain unripe nature and could be seen as an extension of shelf-life.

4. CONCLUSION

The study result showed that citrus Valencia essential oil is a good natural fungicide as the microbial load of the treated fruit kept on decreasing with the advancement of the storage day and with the total analysis of twenty days. The result also showed that citrus Valencia essential oil could be a good substitute for synthetic mango fruits shelf-life extender, as the treated fruits of the Julie went for sixteen days at room temperature as opposed to seven days for the control. Meanwhile, the Broken and John varieties both went for twenty-three days as opposed to ten and nine days for their controls respectively. Also, citrus Valencia essential oil from the result of the sensory attribute can be seen or recommended as a potential fruit shelf-life extender.

COMPETING INTERESTS

Authors have declared that no competing interests exist

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