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Research Article

EVALUATION OF SYNERGISTIC EFFECT OF EVAPORATIVE COOLING SYSTEM AND POTASSIUM PERMANGANATE ON EXTENDING THE SHELF LIFE AND QUALITY OF PLANTAIN

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ABSTRACT

Introduction: Plantain is a climacteric fruit, which means that as it ripens, it increases its respiration rate and ethylene production. Therefore losses are recorded along its production chain value. Post-harvest loss is a major problem limiting the production of plantain in African due to unavailability of established storage conditions that can guarantee long shelf life. In the quest of extending the shelf life and quality of plantain, this study was carried out to evaluate the synergistic effect of Evaporative cooling system (ECS) and Potassium permanganate (KMnO4).

Methods: Unripe plantain fruit were stored under four different condition, ECS, KMnO4 only, ECS with KMnO4 and a control. The storage was done for a period of 12 days with laboratory analysis carried out through this period to analyze the quality of the stored fruits. The pH, weight loss, Total soluble solid (TSS), peel color, Total titratable acid, firmness test and dry matter was carried out.

Result: The pH, which is a major factor in determining the degree of ripening of fruit was obtained to be 4.85, 4.94, 5.00 and 5.77 for control, KMnO4, ECS and ECS with KMnO4 storage condition respectively. Also, the TSS which is also directly proportional to the degree of ripeness was recorded to be 24.00, 21.00, 12.10 and 10.80 for control, KMnO4, ECS and ECS with KMnO4 storage condition respectively. The least percentage weight loss was obtained in ECS with KMnO4 storage condition which is favorable to a better firmness result. 31%, 15.13% and 11.11% weight loss was obtained in control, KMnO4 and ECS storage condition. After day 6 of storage, the plantain fruits in ECS and ECS with KMnO4 ¬¬storage condition maintained their stage 1 characteristics as different from what was obtainable in control and KMnO4 storage. At the end of the storage period, the quality of the stored plantain fruits stored in ECS with KMnO4 was examined to be better in color, firmness, weight loss, pH, TSS and dry matter.

Conclusion: When compared to the individual performances of KMnO4 and ECS, it can be concluded that the synergistic effect further extend the shelf life and quality of plantain fruits.

Keywords: Plantain, ECS and Potassium Permanganate

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INTRODUCTION

Banana (Musa paradisiaca L.), often known as plantain, is a big herb with a pseudostem made of leaf sheaths that belong to the Musaceae family. It is one of the most significant and widely farmed fruits in tropical areas around the world since it is accessible all year and is relatively inexpensive. The banana is a climacteric fruit, which means that as it ripens, it increases its respiration rate and ethylene production (Calberto *et al.,* 2012). Bananas cannot be preserved for a long time under normal conditions due to their climacteric nature. The short postharvest life restricts local and international trade, which is a key issue in banana farming, particularly in underdeveloped nations. As a result, the shelf life and quality of bananas have improved.

Bananas are commercially forced to ripen using ethylene, which reduces the marketing life from 3 to 5 days, depending on ethylene treatment circumstances, and post-treatment holding temperature. Fruit ripening is typically marked by a loss of green color, pulp softening, and an increased metabolic activity, which is followed by shriveling and rotting (Leng *et al.,* 2013). The presence of ethylene in the atmosphere has long been a source of concern for unripe climacteric fruits during postharvest handling since it has been shown to hasten ripening, senescence, abscission, and physiological problems. To minimize ethylene biosynthesis and ensure quick clearance of ethylene emitted from the produce's surrounding atmosphere, ethylene activity must be avoided during storage.

The use of an ethylene absorber reduces the influence of ethylene on fruit, extending shelf life, and improving postharvest quality. Potassium permanganate ($KMnO_4$) is a stable purple solid with a strong oxidizing ability that easily oxidizes ethylene (Wills and Warton, 2004). Because it oxidizes ethylene into carbon dioxide (CO_2) and water, $KMnO_4$ is very effective at lowering ethylene levels (Elzubeir *et al.,* 2017). $KMnO_4$ is well-known as a postharvest anti-ethylene component that helps perishable fruits last longer (Sujayasree and Fasludeen, 2017). With the treatment of $KMnO_4$, Ketsa *et al.,* (2000) and El-Naby (2010) reported delays in banana ripening and improved post-harvest quality. The use of potassium permanganate to remove ethylene slows banana ripening (De Souza Prill *et al.,* 2012). Because direct application of $KMnO_4$ solution to bananas is undesirable because it stains the peel color blue, $KMnO_4$ is applied within a carrier. For bananas, a low-density, low-absorbent, and $KMnO_4$-inert carrier are strongly recommended (Kader and Saltveit, 2002).

Bananas must be stored properly to extend their shelf life. Controlling the temperature and relative humidity of the storage room is essential for proper storage (Susan and Durward, 1995). When dry air travels over a wet surface, evaporative cooling occurs; the faster the rate of evaporation, the greater the cooling. The humidity of the surrounding air affects the efficiency of an evaporative cooler. Because very dry air can absorb a lot of moisture, it cools down faster. In the extreme situation of completely saturated air, no evaporation can occur, and no cooling can occur. Evaporative cooling structures are often built of porous materials that are fed with water. The material is blown with hot, dry air. The water evaporates into the air, increasing the humidity while also lowering the temperature (FAO, 1995).

Low temperatures extend storage life by slowing the rate of respiration and inhibiting the growth of spoiling microorganisms (Roura *et al,* 2000; Watada *et al.,* 1996). Although refrigeration is widely used, bananas have been found to be susceptible to chilling harm when stored in a residential refrigerator for an extended period of time (Shewfelt, 1994; Olosunde *et al.* 2009). Aside from that, the lack of reliable power and the poor income of farmers in remote areas make refrigeration prohibitively expensive.

FAO (1983) proposed for a low-cost storage technique for fruits and vegetables based on the principle of evaporative cooling, which is simple and moderately efficient. The primary idea relies on evaporative cooling.

There is still a lot of work to be done with this species in terms of ethylene absorbers such as potassium permanganate and evaporative cooling. As a result, the goal of this study is to see how potassium permanganate affects the quality and post-harvest preservation of banana fruit while kept at a cold temperature.

METHODS

Experimental details

Freshly harvested bunches of green but mature unripe plantain were bought from the market. The bunches were de-handed and divided into fingers. The fruits of uniform shape, size, color, and free from blemishes were selected and washed with tap water to remove latex, latex stains, soil, and other dust particles and then air-dried.

Two ECS (brick in brick) were used for the storage of the plantain, four fingers of plantain were placed in each of the ECS, and 10 g of potassium permanganate were kept in a pan and placed inside one of the ECS. Four fingers of plantain were kept at a room temperature and used as control.

Observations

Weight loss

On the 1st day, the fruit samples were weighed on a computerized weighing balance, and this was repeated at 4, 8, and 12 days. The weight loss during storage was stated as a percentage and determined using the formula:

$$WL\ (\%) = \frac{W_I - W_F}{W_I}$$

Where, WL=Weight loss (%), W_I=Initial weight (g), and W_F=Final weight (g) of fruit sample

Shelf life

The development of discoloration, such as darkened skin, off-flavor, fungal assault, and skin shriveling, was used to determine the shelf-life of fruit. The end of shelf-life was defined as the point at which more than half of the stored fruits were unfit for consumption.

Titratable acidity (TA)

On the first and last days of the study, TA was calculated. The acidity was calculated using industry standard techniques (AOAC, 2005). Using phenolphthalein as an indicator, a total of 10 mL of clear fruit juice from each treatment was titrated against a standard 0.1 N sodium hydroxide (NaOH) solution. The fruit's titratable acidity was then expressed as a percentage using the formula:

$$TA\ (\%) = \frac{N_B \times V_B \times MEF_A}{V_s} \times 100$$

Where TA=Titratable acidity (%), NB=Normality of the base (NAOH), VB=Volume of the base (mL), MEFA=Milliequivalent factor of the predominant acid, that is, citric acid (0.0064).

Days to change of peel color

The days from the date of storage to the date of peel color change in each banana finger for all treatments were visually noticed and documented using a standard banana color chart, and the averages were calculated appropriately (Table 1).

Total soluble solids (TSS) (Brix)

Using a hand refractometer, the TSS (TSS Brix) was determined (Shibuya optical co., Ltd Japan). After cleaning, distilled water was used to reset the equipment to zero. Then, a specified amount of banana pulp solution was dropped on the refractometer's Prism-plate, and the lid was placed over it to cover it. The TSS measurement was taken.

Fruit pH

A pH meter was used to determine the pH of the fruit pulp (Hana Instrument, HI8417, Italy). As the fingers ripened, the pH was measured. To achieve a homogeneous fruit concentration, 5 g of fruit pulp was crushed; then, 50 mL of distilled water was added. Before introducing the pH meter into the sample, it was calibrated at four and seven readings before being inserted into the samples. The pH rod was cleaned with distilled water each time.

RESULTS AND DISCUSSION

Results

The pH of the plantain was observed to reduce across each storage method through the period of storage. The reduction in the pH is a factor of the rate of ripening of the fruit. As obtained in the Table 2, plantain under the control storage has the lowest pH of 4.85 showing tendency of quick ripening follow by $KMnO_4$ and ECS storage whereas the pH obtained for plantain stored under the ECS+$KMnO_4$ storage was high amidst all other conditions. This shows that the pH of plantain stored in the last treatment as shown in the table maintain a better pH and slow ripening state compare to others.

TSS which is said to be directly proportional to the degree of fruit ripening as obtained in the Table 3 above shows that plantain stored in the control has its TSS value high in control and $KMnO_4$ conditions while a low TSS in ECS and ECS + $KMnO_4$ with, respectively.

The degree of ripening in the two ECS treatment was recorded to be better in the ECS + $KMnO_4$ treatment. A slow increment in the TSS under this treatment was recorded as seen in the Table 3 above meanwhile there was more than a 100% increase in TSS value from Day 3 to Day 6 in other storage conditions as against what was obtained what was obtained in ECS + $KMnO_4$.

The dry matter of plantain at maturity has been used as a measure of its eating quality. Spoilage increases with increase in dry matter. As obtained in Table 4 above, the dry matter was least in ECS+$KMnO_4$ and increasingly at ECS, $KMnO_4$, and control, respectively.

Table 1: Plantain fruit peel color description

Ripening stage	Peel color description	Ripening physiological phase
1	Green	Pre-climacteric
2	Pale green	Pre-climacteric
3	Pale green with yellow tips	Onset to climacteric
4	Yellow: Green – 1:1	Climacteric
5	More yellow than green	Climacteric
6	Pure yellow (completely ripe)	Climacteric
7	Yellow with black specks (senescent spots developing)	Onset to senescence
8	Yellow: Black (1:1)	Senescence
9	More black than yellow	Senescence

Source: Baiyeri, 2005; Baiyeri and Tenkouano, 2008; Dadzie and Orchard, 1997; Ferris, 1991

The effect of $KMnO_4$ in the ECS treatment with the least dry matter value was well noticeable.

Table 5 above shows a general increase in total titratable acid (TTA) during ripening from 0.08 to 0.31. The TTA after day 12 for plantain fruit under $KMnO_4$ and ECS with $KMnO_4$ respectively, was found to be the same while fruit in control has its TTA has the highest. Meanwhile, TTA of plantain fruit stored under ECS condition has the least value of 0.21.

There are noticeable changes in the color of the plantain peel across the experimental period, as showed in Table 6 above. At day 6, the fruit under ECS and ECS+$KMnO_4$ storage condition maintained its peel color as different from the changes observed in $KMnO_4$ and control treatment. The plantain fruit under $KMnO_4$ began its climacteric ripening phase at day 6, while the fruit at control storage was already close to senescence ripening phase with both having yellow-green and pure yellow peel color, respectively. The fruit under control storage was already completely ripe.

On day 9, fruits under ECS+$KMnO_4$ was still maintaining a pale green color while that of ECS condition having yellow tips on its pale green color. Plantain fruit under $KMnO_4$ treatment became ripen at day 9 while that under control storage was already at senescence ripening phase.

At the end of the storage period, plantain fruit stored under ECS+$KMnO_4$ maintained its pale green color with a yellow tips, while other fruits in the other storage conditions have completely ripen.

Apart from the use of the fruit color to determine the stage of ripening, the weight loss which is simple and quick to monitor can be used to predict the ripening stage of plantains. The increase in weight loss over the storage period has been attributed to the loss of moisture through the stomata cells of the fruit.

The least weight loss recorded was obtained in the ECS+$KMnO_4$ storage condition followed by ECS, $KMnO_4$, and control.

DISCUSSION

The various laboratory analyses were carried out to determine the pH, total titratable acid, TSS, dry matter, color change, and weight loss. The results obtained were compared against a baseline result gotten from the day of commencement of the experiment. Unripe plantain fruits obtained were allowed to undergo ripening through a 12 days storage period. After the 12 days of storage, the fruits had reached last stage of ripening (full yellow). This observation is comparable to the study of Akomolafe and Aborisade (2007), in which plantain stored in wooden cabinets took 15 days to ripen to the full yellow stage. Ferris *et al.* (1999) also observed in their study on the fruit quality, evaluation of plantain, plantain hybrids, and cooking bananas that the plantain hybrids took 10–14 days to fully ripen, almost the same as what was observed in this study. The green life of plantain fruits has been reported to depend on the maturity at harvest and storage temperature.

Plantain fruits stored under ECS and ECS+$KMnO_4$ conditions was said to maintain its peel color after day 6 as different from the changes observed in $KMnO_4$ and control treatments. The fruit under control storage was already completely ripe (Stage 6). This means that effect of $KMnO_4$ and ECS can delay ripening longer than the normal 6 days obtainable in a control condition. Meanwhile, on day 9, plantain fruits under $KMnO_4$ storage treatment became ripen (Stage 6) while it was

Table 2: PH determination

Methods	Day of purchase	Day 3	Day 6	Day 9	Day 12
Control	6.54±0.42^a	5.61±0.3^a	5.00±0.32^a	4.96±0.41^a	4.85±0.57^a
ECS	6.54±0.42^a	6.00±0.2^a	5.72±0.21^b	5.91±0.21^b	5.00±0.32^{ab}
$KMNO_4$	6.54±0.42^a	6.11±0.25^a	5.42±0.3^{ab}	5.00±0.32^a	4.94±0.11^a
ECS+$KMNO_4$	6.54±0.42^a	6.64±0.11^b	6.00±0.11^c	5.94±0.32^b	5.77±0.32^b

ECS: Evaporative cooling system, $KMNO_4$: Potassium permanganate

Table 3: TSS

Methods	Day of purchase	Day 3	Day 6	Day 9	Day 12
Control	1.90±0.30^a	5.00±0.2^a	14.30±1.10^a	20.10±2.45^a	24.00±2.11^a
ECS	1.90±0.30^a	3.70±0.30^b	10.90±1.21^b	11.40±1.52^b	12.10±1.54^b
$KMNO_4$	1.90±0.30^a	4.00±0.31^b	12.50±1.51^b	8.21±12.11^a	21.00±2.54^a
ECS+$KMNO_4$	1.90±0.30^a	2.00±0.40^c	3.20±0.21^c	3.90±0.50^c	10.80±2.11^b

TSS: Total soluble solid, ECS: Evaporative cooling system, $KMNO_4$: Potassium permanganate

Table 4: Dry matter (%)

Methods	Day Of purchase	Day 3	Day 6	Day 9	Day 12
Control	54.42±3.56^a	62.11±2.41^a	62.11±2.41^a	63.51±1.92^a	70.54±2.51^a
ECS	54.42±3.56^a	56.21±2.11^a	56.99±3.2^b	58.24±1.02^b	60.11±2.21^b
$KMNO_4$	54.42±3.56^a	57.54±2.41^a	61.21±2.45^a	62.43±2.11^a	64.22±2.56^b
ECS+$KMNO_4$	54.42±3.56^a	54.97±2.41^{ab}	55.14±3.42^b	56.00±1.00^b	56.71±1.05^c

ECS: Evaporative cooling system, $KMNO_4$: Potassium permanganate

Table 5: TTA

Methods	Day of purchase	Day 3	Day 6	Day 9	Day 12
Control	0.08±0.00^a	0.16±0.03^a	0.22±0.01^a	0.28±0.03^a	0.31+0.03^a
ECS	0.08±0.00^a	0.12±0.03^a	0.14±0.03^b	0.19±0.02^b	0.21+0.02^b
$KMNO_4$	0.08±0.00^a	0.14±0.02^a	0.16±0.02^b	0.21±0.02^b	0.25+0.01^b
ECS+$KMNO_4$	0.08±0.00^a	0.09±0.00^a	0.11±0.00^c	0.12±0.03^c	0.25+0.01^b

TTA: Total titratable acid, ECS: Evaporative cooling system, $KMNO_4$: Potassium permanganate still at Stages 2 and 3 at ECS + $KMnO_4$ and of ECS condition, respectively. At the end of the storage period, plantain fruit stored under ECS + $KMnO_4$ maintained its pale green color with a yellow tips compare to ECS condition which has reach Stage 6 (completely ripen). This shows that there is a synergistic effect of $KMnO_4$ inside ECS to slow down the degree of ripening of plantain fruit.

The pH of the samples varied significantly ($p<0.05$). It ranged from 6.54 (Stage 1) to 4.85 (Stage 9) (Table 2), showing a general decrease in pH during ripening. Anyasi *et al.* (2015) also observed a decrease in the pH of banana during ripening ranging from 6.12 to 5.3 for Stages 2 and 6, respectively. However, Alkarkhi *et al,* (2011) and Opara *et al.,* (2013) observed an in increasing pH ranging from 4.8 to 5.47 in their study. These values fall within the range obtained in this present study, as shown in Table 2. The high pH at the initial mature unripe stage which reduced during the ripening process probably was a result of an increase in the organic acid contents in the fruits (Arvanitoyannis and Mavromatis, 2009). Furthermore, there is said to be a relationship between the pH of the samples and the degree of ripening. As the pH of the fruit decreases, the degree of ripening is quicken, meanwhile synergistic effect of $KMnO_4$ on the ECS storage has help in maintaining the pH of the fruits, as shown in Table 2.

TSS recorded at the early stages of storage was because the available starch is yet to undergo enzymatic degradation to be converted into sugars. Degradation of stored starch in the pulp to sugars increases the TSS of the pulp (Dadzie and Orchard, 1997; Seymour *et al.,* 1993; Seymour *et al.,* 1987; and Zhang *et al.,* 2005). The degree of fruit ripening is allegedly directly correlated with TSS. This affirm what was obtained in Table 3 with the least TSS recorded for fruits stored in ECS + $KMnO_4$ having the least degree of ripening as compare to other storage conditions. The variation in the firmness of plantain over the ripening period was significant. The plantain fruit was firm on the first day of ripening by showing high resistance to the force applied on it. There was a minimal decrease in firmness up to the 6th day of ripening after which there was a drastic decrease in the firmness of the plantain. The firmness level of the fruit was found to be in this order from the minimal, control, $KMnO_4$, ECS, and ECS+$KMnO_4$.

Percentage weight loss of the plantain fruits during storage is presented in Table 7. The percentage weight loss of the plantain fruits stored at different storage methods was significant over the storage days and the ripening stages. The weight of fruit after the period of storage was significant under ECS+$KMnO_4$ storage condition, follow by ECS, $KMnO_4$, and control. The results indicate that apart from the use of the fruit color to determine the stage of ripening, the weight loss (which is simple and quick to monitor) can be used to predict the ripening stage of plantains stored under the test conditions. Baldwin (1994), Yaman and Bayoindirli (2002) stated that the moisture loss mechanism in fresh fruits and vegetables are as a result of differences in the water vapor pressure within the fruits and their storage environment which causes vapor phase diffusion. The cool condition under storage in the ECS has play a major role in slowing down weight loss, whereas the synergistic combo of $KMnO_4$ and ECS has been of great benefit to minimize weight loss compare to other storage conditions for this experimental setup.

Table 6: Plantain peel color change

Methods	Day of purchase	Day 3	Day 6	Day 9	Day 12
Control	1	3	6	8	9
ECS	1	1	1	3	6
$KMNO_4$	1	1	4	6	7
ECS+$KMNO_4$	1	1	1	2	3

ECS: Evaporative cooling system, $KMNO_4$: Potassium permanganate

Table 7: Weight loss (%)

Methods	Weight on day of purchase	Weight after 12 days	Percentage weight loss
Control	225±10.5[a]	156.5±5.32[a]	31% (31.1±2.45[a])
ECS	225±10.5[a]	200.0±6.11[b]	11.11% (11.11±2.21[b])
$KMNO_4$	225±10.5[a]	189.3±7.52[b]	15.13% (15.13±1.43[c])
ECS+$KMNO_4$	225±10.5[a]	210.4±10.45[b]	6.49% (6.49±2.1[d])

CONCLUSION

This study has demonstrated that ECS and KNO4 can both extend the shelf life of plantain fruits independently; however, the combined effect further delays senescence and lengthen shelf-life.

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