Archives of Agriculture and Environmental Science 6(1): 35-41 (2021)
https://doi.org/10.26832/24566632.2021.060105

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes

ORIGINAL RESEARCH ARTICLE

Ripening quality of banana cv. Amritasagor through application of different ripening agents

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ARTICLE HISTORY

Received: 13 January 2021
Revised received: 15 March 2021
Accepted: 21 March 2021

Keywords

Banana
Ethephon
Ripening
Ripestuff^{TM}
Softness

ABSTRACT

Desirable ripened quality banana fruits are important for the consumer acceptability. Banana cv. Amritasagar was treated with different ripening agents like control (R_1), Ripestuff^{TM} @ 42 mg/10 mL water (R_2), Ripestuff^{TM} @ 84 mg/10 mL water (R_3), Ethephone @ 200 ppm (R_4) and Ethephone @ 400 ppm (R_5); and storage durations were 24 h (H_1), 48 h (H_2), 72 h (H_3), and 96 h (H_4). The two factors experiment was conducted with complete randomized design with three replications. Fruits were placed in container (RFL). With the progress of storage duration quality parameters like weight loss (%), peel color, pulp to peel ratio, softness, total soluble solids (TSS), and pH were recorded. Fruits treated with R_3 and R_5 produced uniform yellow color and the highest softness at 96 h. Whereas banana fruits treated with R_2 developed peel colour and softness a bit slower compared to other treatments; and untreated fruits (control) were hard, poor in color and quality, and were not suitable for consumption at 96 h. The highest TSS (%) were found at 72 h treated with R_5 and at 96 h with R_5 including R_3, and R_4 showed the mostly similar TSS (%). Thus, Ripestuff^{TM} @ 84 mg/10 mL water (R_3) and ethephon @ 400 ppm (R_5) can be used maintaining quality and ripening banana for better price of banana growers and traders through avail it at earlier marketing and reduced postharvest loss.

Citation of this article: Yasmin, T., Islam, M.A., Quadir, Q. F., Joyce, D. C., & Bhandari, B. (2021). Ripening quality of banana cv. Amritasagor through application of different ripening agents. *Archives of Agriculture and Environmental Science*, *6*(1), 35-41, https://dx.doi.org/10.26832/24566632.2021.060105

INTRODUCTION

Bananas (*Musa* spp.) are typical climacteric fruit under the family Musaceae. This is considered as one of the top 10 world food crops considering both cash and food crop in the tropics and subtropics (FAO, 2009; Jideani, 2019). Banana is very popular and widely cultivated and world's oldest cultivated plants which can be eaten as both raw and ripened (Hossain, 2014). Both stages are considered as very nutritious like rich in iron, calcium, magnesium, vit A and low fat etc. (Khanum *et al*., 2000; Sharrock and Lustry, 2000; Kumar *et al*., 2012). They are also ideal for patients suffering from gout, arthritis, kidney disorders, blood pressure, and heart problems. Banana ranks first considering area coverage and it covered about 31.6% of fruit area in Bangladesh (BBS, 2018). As a climacteric fruit, bananas are usually harvested green mature and ripened with ethylene gas to achieve more uniform and predictable ripening (Abeles *et al*., 1992; Hofman *et al*., 2001; Montalvo *et al*., 2007; Tovar *et al*., 2011). The color and quality of ripe fruits are important considerations to the consumer and commercial growers as well. During ripening, banana peel turns to lighter green, and then to yellow as chlorophyll is broken down, and the pulp becomes softer and sweeter due to conversion of sugar to starch (Robinson, 1996; Mohapatra *et al*., 2010). There are some chemical ripening agents are used in developing country as well as Bangladesh not following proper dose. Different ripening agents like calcium carbide (CaC_2), ethylene (C_2H_4), ethephon (2-chloro ethyl phosphoric acid) are used for the ripening of immature

fruits rapidly with attractive colour for consumers (Barry and Giovannoni, 2007; Prasanna *et al*., 2007; Singh and Dwivedi, 2008). Recently, some growers and traders in Bangladesh are commercially using some chemicals namely Ripen, Gold-Plus, Profit, etc. for the ripening of tomato, papaya, and banana, directly to the fields and processing areas (Bondad and Pantastico, 1972; Assani *et al*., 2001). These chemicals change nutritional properties of fruits and vegetables and lead serious health hazards to human beings like cancer, skin irritation, diarrhea, liver disease, kidney disease, gastrointestinal irritation with nausea, vomiting, diarrhea, cardiac disturbances, central nervous system depression and cardiac abnormalities etc. (Per *et al*., 2007; Rahman *et al*., 2008). On the other hand, Ripestuff^{TM} an encapsulated ethylene-α-cyclodextrin (α-CD) inclusion complex (IC) powder is a potential alternative source of ethylene for fruit ripening which has been patented in 2019 (Ekman *et al*., 2019) which has been leaded by Bhandari and his group on behalf of the University of Queensland, Australia. It offers a promising and safe alternative to calcium carbide for batch-ripening of fruit in newspaper-lined baskets, as is the current commercial practice in the Philippines (Asif, 2012; Ekman *et al*., 2019). Also, it is useful for transit ripening of fruits; and reduce the postharvest loss (Bhandari and Ho, 2014; Ho *et al*., 2011ab; Ho *et al*., 2016; Capozzi *et al*., 2017). Postharvest loss in Bangladesh is recorded 26.63% (Molla *et al*., 2012). Overall, it is important to identify the proper dose for different fruits to ripen and to attract the consumer, ultimately reduce the postharvest loss (Ibarra-Garza *et al*., 2015). Because, after harvesting of banana or any fruits, the metabolic reactions like respiration and transpiration continues and deterioration occurs after the fully used of reserve foods (Haia *et al*., 2009). Recommended ripening conditions encompass 10–100 mL/L ethylene and RH of 85–90% is generally recommended for ripened fruits to minimize weight loss at 18–20°C for 24–72 h (Saltveit, 1999; Hofman *et al*., 2001; Lalel *et al*., 2004; Sivakumar *et al*., 2011; Wills *et al*., 2007; Yahia, 2011; Kader, 2008).

Food safety is an essential to maintain nutrition and control health hazard is the most key issue for the human being health issue. Considering all the issues, optimization of the dose of ripening agents like Ripestuff^{TM} and ethephon to ripen banana cv Amritasagor with maintaining the quality need to be investigated. Amritasagor cultivar is the very popular cultivar of banana in Bangladesh. So, properly ripening of banana can help to earlier market and better price for the growers and traders and to reduce the postharvest loss.

MATERIALS AND METHODS

Collection of materials

Green and matured banana bunches cv. Amritasagor of uniform sizes and shape was harvested from Horticulture Farm of Bangladesh Agricultural University (BAU), Mymensingh. Both upper and lower 1-2 hands were cut off to maintain uniform shape and size. The bananas were collected early in the morning and transferred to the laboratory of the department as soon as possible by van with careful handling to avoid mechanical injury. Banana bunches were cooled by air condition quickly to remove the field heat. The temperature and relative humidity inside the laboratory were 25 -27°C and 80-85%, respectively.

Experimental design

The two-factor experiment was laid out in Complete Randomized Design (CRD) with three replications. Each replication consisted of three fruits.

Experimental treatments

Factor A (Ripening agents): R	Factor B (Treatment time): H
R_1: Control	H_1: Twenty-four (24) hours
R_2: Ripestuff^{TM} @ 42 mg/10 mL water	H_2: Forty-eight (48) hours
	H_3: Seventy-two (72) hours
R_3: Ripestuff^{TM} @ 84 mg /10 ml water	H_4: Ninety six (96) hours
R_4: Ethephon @ 200ppm	
R_5: Ethephon @ 400ppm	

So, total number of fruits were 5x4x3x3= 180 nos.

Preparation of ripening agents

Two ripening agents with two different concentrations were used and their preparation is mentioned below:

Ripestuff^{TM} (Encapsulated ethylene-α-cyclodextrin inclusion complex) powder

The Ripestuff^{TM} was manufactured at the University of Queensland (Brisbane, Australia) by following Ho *et al.* (2011b) were used for this experiment. Ripestuff^{TM} powder were weighed 42 mg and 84 mg accordingly by electric balance and quickly transferred to the 50 ml vial with 10 mL water. Earlier vial lead was perforated with syringe and kept close by scotch tape. Fruits were kept in 15 L container (RFL) and scothtape of vials were removed for releasing ethylene gas uniformly to ripen banana (Figure 1). In case of control, 10 mL water only was in vial for the same relative humidity or environment for the banana.

Ethephon: Ethephon (48% SL) for dip treatment of banana was used under the brand name Etheplus. Ethephon solutions were prepared to make 200 ppm and 400 ppm. Bananas were treated with the respected solution by dipping for 3 min. Subsequently, fruits were left on the paper for drying and then these were kept into the 15 L air tight plastic container (RFL) to observe the performance of ripening through ethephon. Finally, all the containers were covered tightly at the same time and data were recorded for each treatment. Temperature and relative humidity of both inside and outside of the container was recorded regularly.

Data collection

Physical parameters: The weight loss (%) at different hours (24, 48, 72 and 96 hours) was calculated by subtracting final weight from the initial weight of the fruits and appraisals were made for

Figure 1. *One vial placed inside the container (leaft side and container set up for the experiment shown (right side)*

physiological loss in weight. The physiological loss in weight was calculated on fresh weight basis by following formula: (A - B) /A x 100 where A is the fruit weight just before storage and B is the fruit weight after different hours storage period. Pulp to peel ratio was measured through separation of peel from the pulp. Both the weight of peel and pulp were taken and calculated by dividing the fresh weight of pulp with the fresh weight of peel.

Quality parameters: Peel color change is the important parameters which was recorded using the numerical rating scale of 1-7 and it is the modification of the study of the United Fruit Sales Corporation (1975). Peel color from stages 1-7 considered: 1=dark Green, 2= pale green, 3=pale green with yellow tips, 4=half green half yellow, 5=more green than yellow, 6=pure yellow, 7=yellow with black coalescing spots.

Days required to reach different stages of softness during storage and ripening were determined after every 24, 48, 72 and 96 hours according to the treatment by using numerical rating scale of 1-5, where, 1 = hard green, 2 = sprung, 3 = between sprung and eating ripe, 4 = eating ripe and 5 = over ripe.

Total soluble solids (TSS) content of banana fruit pulp was estimated by using Abbe's refractometer. A drop of banana juice squeezed from the pulp was placed on the prism of the refractometer and recorded as % brix. Temperature corrections were made by using the methods described by Ranganna (1986). pH of the pulp was measured with pH meter.

Statistical analysis

The collected data on various parameters were statistically analyzed by analysis of variance (General Linear Model procedure) following Duncan's Multiple Range Test (DMRT) and Tukey's pair wise comparison test ($P<0.05$) using Minitab Version 17 (Minitab Inc., State College, PA, USA).

RESULTS AND DISCUSSION

The experiment was conducted with a view to study the effect of different doses of ethephon which is commonly available in Bangladesh and Ripestuff^{TM} powder recently invented in Australia were used to ripen banana in respect of physico-chemical changes.

Physical characters

Weight loss (%) of banana: Water loss from banana is usually occurs through the peel. The weight loss (%) of banana fruits increased during ripening process (Figure 2). The highest weight Loss of banana was observed with R_3 (2.80%) during the storage period of 72 h. The lowest weight loss was recorded during 72 h in control fruits (1.60%) and these fruits were green and hard in texture. The weight loss rapidly increased in the treatments with R_2, R_3, R_4 and R_5 during the period of 72 h to 96 h, and there was no significant difference between R_2, R_3, R_4 and R_5 at 96 hours. The increase in weight loss during ripening of banana fruits by ethephon or Ripestuff^{TM} application may be due to upsurge in respiration rate of the fruit. An increased weight loss was reported in guava fruits during ripening process caused by ethylene application (Mahajan *et al.*, 2008). Weight loss in stored or transported fruits could be traced to moisture loss during transpiration (Asiedu, 1987; Burdon *et al.*, 1991). Fruit can sustain a substantial weight loss due to transpiration and respiration with only a minor reduction of food quality.

Softness: The softness of banana fruits increased during ripening period in all treatments (Figure 3). According to the rating scale, the highest rating scale 4.9 and 4.7 (where, *4 = eating ripe and 5 = over ripe)* were found from the R_4 and R_5 treated banana fruits, respectively at 96 h. The second highest range of softness, 4.0 and 3.88 (*3 = between sprung and eating ripe, 4 = eating ripe*) were found from R^3 and R^2 treated banana fruits, respectively. Untreated fruits rating scale were 1.67 (where, *1 = hard green, 2 = sprung*) at 96 h is not considered for edible. Whereas, treated fruits were considered as edible at 96 h, and R_2 treated fruits increased softness slowly but R_3 treated fruits increased softness earlier and remain stable at the end 24 h. Mahajan *et al.* (2010) found the uniform development of yellow color banana fruit treated with ethylene at 96 h.

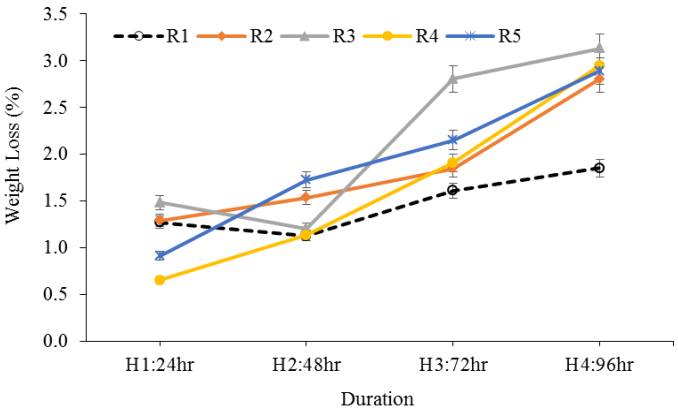


Figure 2. *Effects of different ripening agents on % weight loss of banana at different duration. R_1: Control, R_2: Ripestuff™ @ 42 mg/10 mL water, R_3: Ripestuff™ @ 84 mg /10 ml water,R_4: Ethephon @200ppm, R_5: Ethephon @ 400ppm.*

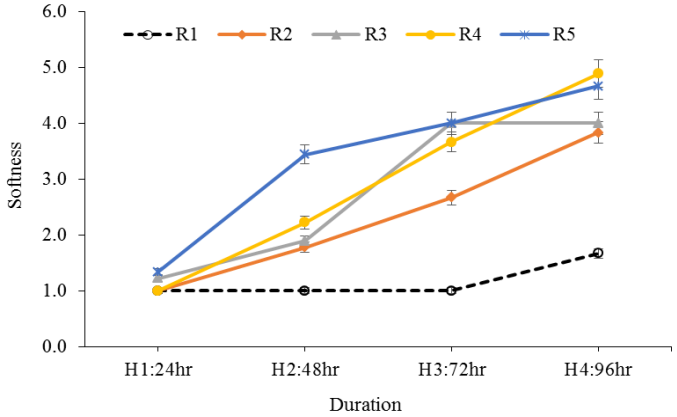
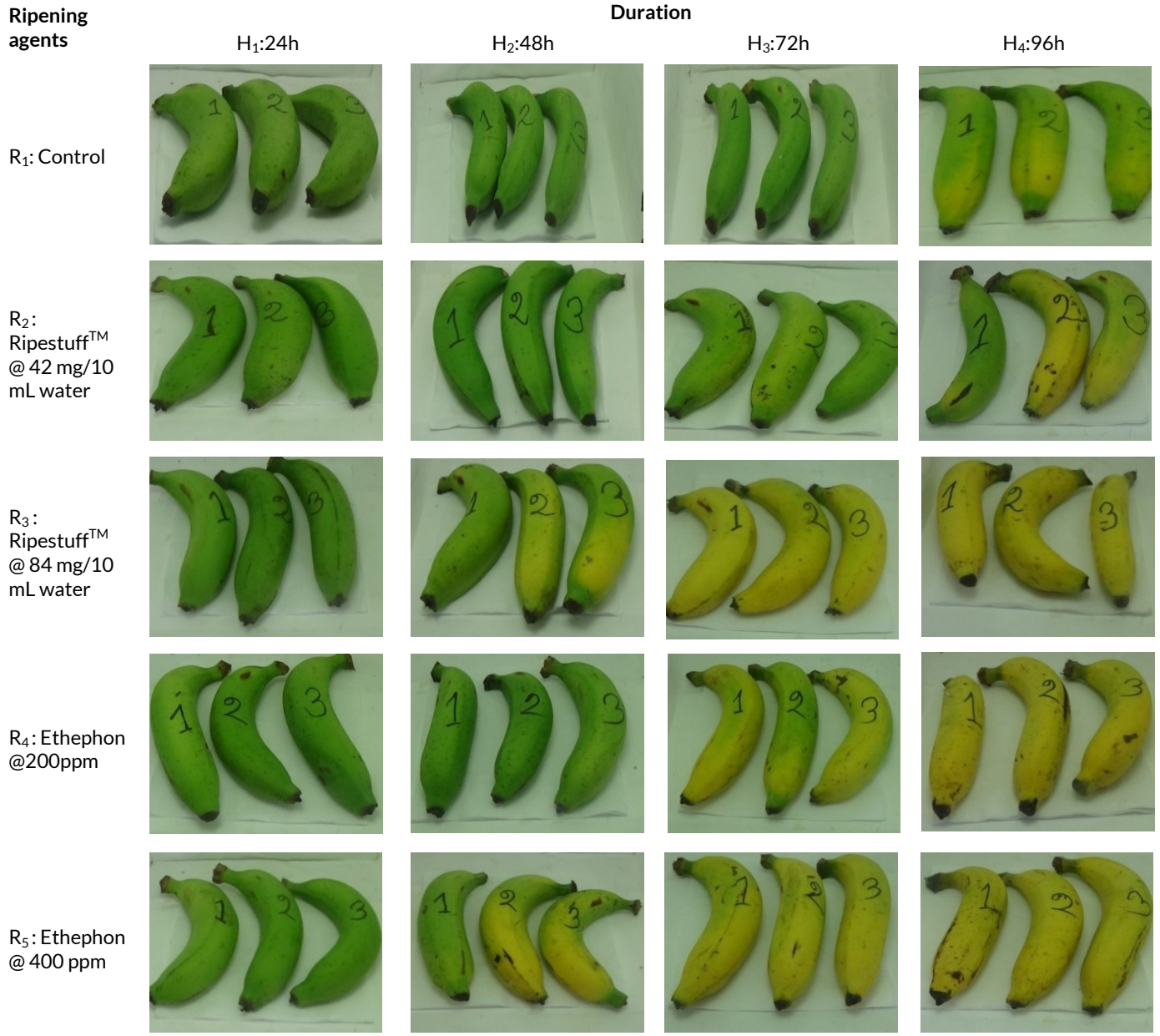


Figure 3. *Effects of different ripening agents on softness of banana at different duration. R_1: Control, R_2: Ripestuff™ @ 42 mg/10 mL water, R_3: Ripestuff™ @ 84 mg /10 ml water, R_4: Ethephon @200ppm, R_5: Ethephon @ 400ppm Rating scale of 1-5, where 1 = hard green, 2 = sprung, 3 = between sprung and eating ripe, 4 = eating ripe and 5 = over ripe.*



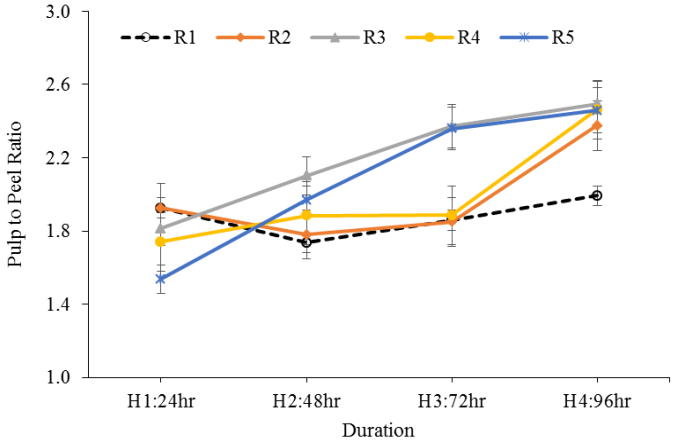


Figure 5. *Effects of different ripening agents on pulp to peel ratio of banana at different duration. R_1: Control , R_2: Ripestuff™ @ 42 mg/10 mL water, R_3: Ripestuff™ @ 84 mg /10 ml water, R_4: Ethephon @200ppm, R_5: Ethephon @ 400ppm.*

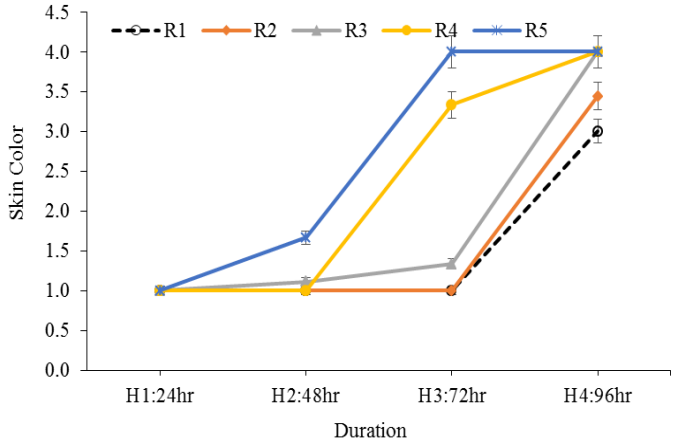


Figure 6. *Effects of different ripening agents on skin color of banana at different duration. R_1: Control, R_2: Ripestuff™ @ 42 mg/10 mL water, R_3: Ripestuff™ @ 84 mg /10 ml water, R_4: Ethephon @200ppm, R_5: Ethephon @ 400ppm; Peel color from stages 1-7 considered: 1=dark Green, 2= pale green, 3=pale green with yellow tips, 4=half green half yellow, 5=more green than yellow, 6=pure yellow, 7=yellow with black coalescing spots.*

The softness trend was found in tomato using the different concentration of aqueous solution of ethephon and ethylene gas (Dhall and Singh, 2013). Also, they found the differentiation of ripening time using different ripening agents where ethephon promote earlier ripening compared to ethylene gas. In this experiment, banana fruit had the green life colour during the starting of treated condition, and ripening was initially initiated after 48 h showing the uneven green colour in the treated fruits (Figure 4). During the 96 h, banana fruits are fully yellow colour which are treated with R_3, R_4 and R_5 and articulately different from the control fruits. So, response of ripening rate is influencing by important factors like concentrations and exposure time dependent (Zhu *et al.*, 2015). The hard or semi hard banana fruits are not preferable by most of the consumers in our country and hence need to develop artificial ripening for the desirable quality banana fruits enhancing consumer acceptability.

Pulp to peel ratio: The remarkable pulp to peel ratio was observed at 72 h and earlier there were no significant different of control and treated banana fruit plants (Figure 5). The highest pulp to peel ratio (2.36) was found from R_3 (Ripestuff™ 84 mg/10 mL water) and R_5 (ethephon 400 ppm) at 72 h recorded time. The rest fruits treated by R_2 and R_4 including the control banana fruits pulp to peel ratio was nearly same and it was around 1.8. Trend of the linear line of R_2 and R_4 treated fruits pulp to peel ration sharply reached to 2.4 from 1.8 within last 24 h, but the linear line of R_3 and R_5 treated fruits slowly rise up at the last 24 h. It indicates the highest level of softness and uniform color index found in Figure 3 and 4. Increasing the sugar content in the pulp could allow the water to move from the pulp to peel, hence pulp to peel ratio was increasing with increase in total soluble solid (TSS) and moisture content. Higher pulp to peel ratio during fruit ripening suggested changes in sugar concentration in the tissues. That's why the skin colour changing index was sharp at the last 24 hours (Figure 4).

Quality parameters

Fruit color: The fruits treated with Ripestuff™ or ethephon solution recorded significant improvement in yellow colour of the peel compared to untreated control, which remained greenish soft with dull appearance (Figures 4 and 6). The fruits treated with Ripestuff™ and ethephon solution recorded uneven yellow color of the peel 48 h and remarkable skin color observed at the last 24 h from 72 h to 96 h. During the 72 h storage, recorded skin color was 3 (pale green with yellow tips) and 4 (half green half yellow) of R_4 and R_5 treated fruits, respectively. On the other hand, R_3 treated fruits color 1.3 (between dark green and pale green) at 72 h reached to 3.4 (between pale green with yellow tips and half green half yellow) which is nearly same of R_4 and R_5 treated fruits (4: half green half yellow) at 96 h. The green color of unripe fruits is due largely to the presence of chlorophylls. It is known that ethylene gas and ethephon accelerate the chlorophyll degradation or synthesis of carotenoids by stimulating the synthesis of chlorophyllase enzyme which caused chlorophyll degradation and expression of β-carotene pigments in green tissue of many fruits (Kulkarni *et al.*, 2004; Mahajan *et al.*, 2008; Reyes and Paull, 1995). In this experiment, ethylene application through ethephon or Ripestuff™ bind the receptor of ethylene which forms an activated complex leading to a wide variety of physiological responses including ripening (Pang *et al.*, 2007).

Pulp pH: During fruit ripening organic acids are decreased, because most of the acid are used in the process of respiration and changed to sugars. The pH level of banana decreases when it ripens. When the banana ripens, there is a slightly increase in the acidity of banana as a result the pH level decrease when it becomes more acidic. Banana fruits treated with Ripestuff™ and ethephon pH was decreasing trend but pH recorded of R_5 treated fruits were significantly different from other treatments at 48 h and 72 h, whereas recorded pH at 96 h were not significantly different (Figure 7).

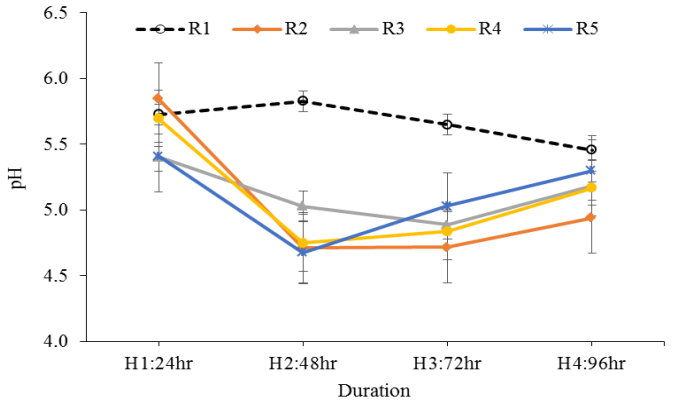


Figure 7. *Effects of different ripening agents on P^H of banana at different duration. R_1: Control, R_2: Ripestuff™ @ 42 mg/10 mL water, R_3: Ripestuff™ @ 84 mg /10 ml water, R_4: Ethephon @200ppm, R_5: Ethephon @ 400ppm*

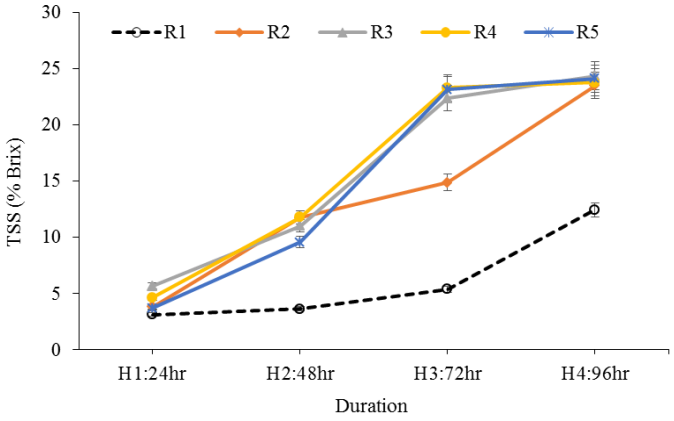


Figure 8. *Effects of different ripening agents on total soluble solids of banana at different duration. R_1: Control, R_2: Ripestuff™ @ 42 mg/10 mL water, R_3: Ripestuff™ @ 84 mg /10 ml water, R_4: Ethephon @200ppm, R_5: Ethephon @ 400ppm.*

Total soluble solids (TSS): The TSS content of fruits increased during ripening irrespective of treatments (Figure 8). The TSS content of banana were maximum (24.12%) with R_5 (Ethephon @400 ppm) and nearly similar TSS was found from the rest treated banana with Ripestuff™ and ethephon at 96 h. It indicates that the banana reached in peak as edible during the 96 h. Mahajan *et al.* (2010) found the maximum TSS (19%) of 'Grand Naine' cultivar of banana at 4 days treated with Ethephon. In our experiment, the lowest TSS found from the untreated fruit at 96 h (12.46). TSS study and skin index (Figure 4 and 8) clearly showed that R_2 (Ripestuff™ @ 42 mg/10 mL water) influencing to ripen slowly and it can give opportunity to consume for more time compared to the treated R_3, R_4 and R_5 treated fruits. Because, R_2 treated fruits skin color and TSS is also the significantly lower compared to the other treated fruits but significantly different from the untreated fruits (control) at 72 h. Fruits contain many compounds, which are soluble in water such as sugars, acids, vitamin C, amino acids and some pectin, are the total soluble solid (TSS) contents of the fruits. The TSS content of fruits showed the increasing trend during the storage time and similar trend was found in case of different fruits (Hassan *et al.*, 2009; Islam *et al.*, 2013; Monira *et al.*, 2015; Monira *et al.*, 2016). The increase in TSS during ripening may result from an increase in concentration of organic solutes as a consequence of water loss; also due to numerous anabolic and catabolic processes taking place in the fruit preparing it for senescence (Ryall and Pentzer, 1982; Kulkarni *et al.*, 2011).

Conclusion

Exposed green mature banana fruits to Ripestuff™ and ethephon at different concentrations followed by storage ensure the faster and uniform ripening in 96 h with development of uniform yellow colour and consumer acceptability. Overall, a bit earlier softness, TSS (%) and skin color indexing was found from the R_3(Ripestuff™ @84 mg /10 ml water) and R_5(Ethephon @400ppm) treated banana fruits compared to other treated fruits; and it can be considered as safe ripening agents and commercially benefit to growers and traders due to earlier avail the banana as per consumer preferences and less postharvest loss.

ACKNOWLEDGEMENTS

Thanks to Professor Bhesh Bhandari, The University Queensland, Australia for providing the Ripestuff™; and Horticulture farm and Laboratory of Agricultural Chemistry, Bangladesh Agricultural University for providing uniform shape and size banana; and quality analysis to conduct this experiment.

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