ENHANCING SHELF LIFE OF BANANA AND PACKAGING THROUGH EDIBLE COATING SOLUTIONS AND CLING SHEET: AN ECO-FRIENDLY APPROACH

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(Received 23rd Mar 2023; accepted 22nd Aug 2023)

Abstract. The use of synthetic materials are damaging not only the health of growing populations but also our environment equally. To overcome such issues, natural plant extracts and ecofriendly packaging materials are gaining popularity among stakeholders. Banana is one of the most important crop of the world which suffers from post-harvest losses especially during transportation and storage, which hampered export market as well. An experiment was conducted by applying different edible coating solutions of plant extracts such as Marigold (20%), Guar gum (2%), Neem oil (4%), *Aloe vera* (30%), Ginger (10%), Garlic (10%) with cling sheet packaging material on five varieties of banana namely Pishang, Brazilian 10, William 11, Grandnain 9 and Basrai. Results revealed that *Aloe vera* (30%) coating solution with cling sheet as packaging material showed the best results in comparison to other treatments by reducing weight loss percentage, enhancing firmness, slowing down the change in taste and color of banana peel, increasing the pH value gradually, reducing sugar content and decreasing gradually the titratable acidity and considerable variation in protein contents. In conclusion, Brazilian 10 showed the best performance against all treatments and this variety can be stored for more than 4 weeks in the summer season. Hence, the application of *Aloe vera* gel spray is recommended not only on banana but for other fruits to extend shelf life.
Keywords: *eco-friendly, value addition, Brazilian-10, natural plant extracts, post-harvest losses*

Introduction

Banana is the second most grown horticultural crop in Pakistan particularly in the southern parts of the country including Sindh and Punjab. It is cultivated on 66,000 acres with production of about 5-6 tons (Azeem et al., 2016). Bananas and plantains (Musa spp.) are the fourth most significant crops in the world as both of them consumed as staple food and cash crop (Salacinas, 2019). Washing, grading, sorting, storage and transportation are all basic steps of postharvest management that provides harvested fruits or vegetables quality and safety (Sparks, 1989). In the world, the total crop area of banana is 11.13 million hectare which is producing about 97.38 million tons of banana and plantains.

Banana is a perennial herb with leaf sheath that makes trunk known as pseudostem. Banana plant varies in height from 1.5-8 m and basically divided in to starchy kind which is known as plantain and desert known as banana (Abiso et al., 2018). Different edible coating solutions with packaging materials are in use to enhance shelf life of fruits and postharvest quality. A lot of banana fruits are damaged at the stage of maturity, which can be overcome through applying various packaging materials. Likewise, coating of different types of edible solutions and natural solvents can reduce fungal infestations (Abiso et al., 2018).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2106_51195140

Banana is a fragile fruit and its post-harvest loss is 25-50% (Amiruzzaman, 1990). Shelf life decreases with the passage of time even by applying different coating solutions and packaging material (Abiso et al., 2018). Losses usually occurred while transporting and selling due to physiological changes, flesh softening and absence of microbial attack resistance (Bains et al., 2017). Therefore, appropriate measures are required to combat post-harvest losses from harvesting to consumption. For shelf life enhancement, various chemical solutions like GA_3 and $KMnO_4$ are applied on the fruit to suppress the ethylene production to extend the shelf life of banana. In this way, bananas can be preserved for time on requirement of consumer (Bains et al., 2017).

To overcome several barriers, plants based natural edible coating solutions are generally proved to be effective and eco-friendly which acts as a layer on cell wall to decrease respiration rate and weight loss percentage. These solutions can directly influence firmness of banana fruit and also provide sheen peel for fruits (Massilia et al., 2016). Several important functions are attributed to edible coating solutions including antimicrobial, antiseptic, antifungal, and antioxidants effects. Further, these edible coating solutions are also play vital role for food stability, safety and quality of fruit products (Massilia et al., 2016). Several reports are available on using edible coating solution on fruits and vegetables to extend the shelf life. Importantly, these coating solutions do not change the nutritional properties. Mostly, *Aloe vera* gel solution is used to extend the shelf life of fruits and vegetables. Essential oil, such as neem oil is also used since it reduces the water loss and color change (Botelho et al., 2016 and Perdones et al., 2014). Neem oil is used as fungicidal and insecticidal for centuries in Asia due to presence of Azadirachtin which is an active compound due to the presence of fungicidal, growth regulating and insecticidal properties (Chaturvedi et al., 2003).

By considering post-harvest management challenges in banana current studies were designed to study shelf life and packaging material evaluation for further practical uses. The present study helps to save bananas for long time with enhanced nutrition, good odor, taste, flavor and appearance.

Materials and methods

Collection of fruits

The unripened bananas were acquired on 08 July, 2019 from the cities of the Sindh province including Tendojam, Tando Allah Yar, Thatta, Tando Mohammad Khan, Mattiari, Khairpur and Haiderabad. Bananas were received at Biodiversity Informatics, Genomics and Post-Harvest Biology Laboratory of Department of Botany, University of Gujrat, Gujrat with GPS coordinates of latitude: 32.639738° N, longitude: 74.166211° E, elevation: 805 ft. Five banana varieties *viz*., Pishang, Brazillian-10, Willium-11, Grandnain-9 and Basrai were obtained. Bananas were washed after harvest and then air dried. They were packed with newspaper in plastic carets. All were packed separately and labelled. Bananas were transported to lab within 24 h after harvest.

Experimental area and design

After receiving, banana packets were opened and remained placed in the lab for half an hour for room temperature adjustment. Then bananas were washed with tap water and dried overnight by air. Next day bananas of same length and weight were selected and grouped. Banana sets were arranged according to completely randomized design

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(CRD). They were grouped as 3 replicates per week and kept for 5 weeks duration to study the shelf life by evaluating various parameters. Samples free from contamination, uniform in shape, size and length were arranged within their groups for each treatment according to experimental design.

Preparation of treatments for experiments

Plant extracts

Marigold flower petals, *Aloe vera* gel, Neem oil, Guar gum, Garlic and Ginger plants were selected based on literature review as these plants known as fungicidal and insecticidal. Due to this these exhibit positive impact in post-harvest management particularly on shelf-life enhancement.

Plant extracts were prepared by dipping plant parts like marigold flowers, *Aloe vera* fresh gel from leaves, neem leaves oil, fresh garlic and ginger fruit parts into distilled water for overnight, then they were filtered through Whatman® filter paper to obtain pure-solution.

Preparation of treatment solutions

Obtained plant extracts were further diluted into various concentrations to prepare different treatment solutions in percentage by adding distilled water. The following steps were performed.

T1: Control (distilled water/untreated).

T2: Marigold flower petals were dissolved in 1 L distilled water to make a 20% solution. Whereas for T3, Guar gum was dissolved in 1 L distilled water to a make 2% solution. For T4, Neem oil was dissolved in 1 L distilled water to make a 4% solution. Likewise, for T5, *Aloe vera* gel was dissolved in 1 L to make a 30% solution in distilled water, while for T6, a 10% solution of Ginger was prepared by grinding it in 1 L distilled water with addition of 0.2 g guar gum. T7, was 10% Garlic solution in which garlic is grinded in 1 L distilled water and add 0.2g guar gum as well to get better results.

Treatments impact

Plant extracts in the form of solutions were applied on different groups (varieties of banana samples) for each treatment by dipping method. Prepared treatment solutions as described above were poured into open trays in different concentrations and then guar gum powder was added into ginger and garlic solutions (protective agent against fungal species). After that selected banana samples of the five varieties were dipped in each tray for 15-20 min, followed by drying for 10-20 min and packed separately with cling sheet. Readings of both morphological and physiological changes were taken at the interval of one week, which consecutively for four-weeks.

Morphological parameters

Weight loss percentage

For weight loss percentage, banana samples were weighed at different stages of the storage. A digital scale for the weighing is used in this experiment with a precision of 0.01 g. Banana samples were weighed on day 0, day 7, day 14, day 21, day 28 and day 35, and the

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weight loss percentage was calculated by using the following formula (Tabassum et al., 2018):

$$\text{Weight loss percentage} = \frac{\text{Initial weight-final weight}}{\text{Initial weight}} \text{ X } 100$$

Firmness

To determine the firmness, penetrometer was used with unpeeled bananas of five varieties with different treatments. The device used was OSK- I-10576, Ogawa Seiki Co., Tokyo, Japan. The mean pressure 'N' was recorded at three points, i.e., middle, proximal and distal position. The firmness was measured in Newton (N) (Babu et al., 2019).

Skin quality color of banana peel

Changes in color during storage were determined on the basis of the characteristics stated by Zewter et al., 2012 with a numerical scaling from 1 to 7 (*Table 1*).

Table 1. *Color scale for Musa acuminata on visual basis as described by USDA (Zewter et al., 2012)*

Score	Color of banana peel
1	Dark green
2	Light green
3	More green than yellow
4	More yellow than green
5	Yellow with green tip
6	Full yellows
7	Flecking

Taste change with ripeness

Taste of samples were evaluated by organoleptic test following score for taste from 1-4 based on its quality and flavor as described in *Table 2*.

Table 2. *Taste scale for Musa acuminata based on taste bud (Abeywickrama et al., 2004)*

Score	Taste of banana pulp
1	Poor taste
2	Fair
3	Good
4	Excellent

Score includes flavor and sweetness of the pulp.

Physiochemical parameters

pH

pH was determined by placing the probes of pH meter in banana pulp solution of all specific samples (Model PH500, CLEAN Instruments Co. Ltd., Shanghai, China). Banana juice was prepared as a 1:1 solution with distilled water.

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Reducing sugar content

0.5 g of fresh fruit sample with 10 mL of ethanol was taken in a test tube and placed in a hot water bath for 1 h at 80℃. After that, 2 mL of solution was cooled down. Then 2 mL of water and 2 mL of 18% phenol were added to the test tube containing the 2 mL of fruit ethanolic extract. At the end, 2 mL of sulfuric acid was added, then the mixture was shaken for 2 min and subjected to absorbance record at 490 nm by using a spectrophotometer (Seedevi et al., 2018).

Titratable acidity (TA)

Titratable acidity (TA) of fruit pulp was measured by reagent method (Islam et al., 2013).
Reagents used were as follows:
NaOH solution of 0.1 N X 100
Methyl red 1% solution
In a conical flask, to 10 mL pulp 2-3 drops of phenolphthalein as an indicator was added and shaken strenuously. Then it was titrated against 0.1 N NaOH solution using a burette until the color turned pink in appearance. Volume of NaOH used for titration was recorded to calculate TA by using above mentioned formula.

Protein estimation

For estimation of protein contents in different banana varieties at different ripening stages, 0.25 mL banana pulp solution was mixed with 10 mL of potassium phosphate. Then the mixture was centrifuged for 15 min at 10,000 RPM on 40°C. After centrifugation, 0.1 mL aliquot was added with 2 mL of Bradford reagent, followed by measuring absorbance at 590 nm by a spectrophotometer.

Total soluble solids

To measure the soluble solids in Banana samples at different ripening stages, 10 g banana pulp was homogenized in 40 mL of distilled water to make banana solution. Then one drop of solution was squeezed on the prism of the refractometer and the range of total soluble solids were visualized within measurement range of 0-32 Brix.

Statistical analysis

Descriptive statistics including mean, standard deviation, and standard error and bar graphs were performed by using Microsoft Excel version 2016. Three-way ANOVA was conducted by general linear model with probability $p > 0.05$ to determine the significance of the results. Main factors were week, variety and treatments. And to examine and visualize final graphic shape of the results, main effects plots were built with the help of Minitab version 17.

Results and discussion

Morphological attributes (first stage experiment)

Weight loss percentage

Weight loss percentage is the important factor to describe the weight observed before and after treatments. The best treatment like *Aloe vera*, Neem oil, Guar gum shows the

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lowest weight loss percentage from week 1 to week 4 in B-10 as compared to other varieties. However, the highest weight loss percentage was observed in Pishang and Basrai variety as compared to control and other varieties (*Fig. 1*).

In *Figure 2*, it can be observed that the value of weight loss percentage within the week gradually increased to show the banana ripeness. Brazilian 10 and William 11 were the best varieties that showed minimum weight loss percentage and retained the banana as unripen by enhancing shelf life for long period. Moreover, treatment five which was *Aloe vera* showed the best output in reducing weight loss. Therefore, week 4, variety B-10 with the treatment of *Aloe vera* showed the best outcome in shelf life.

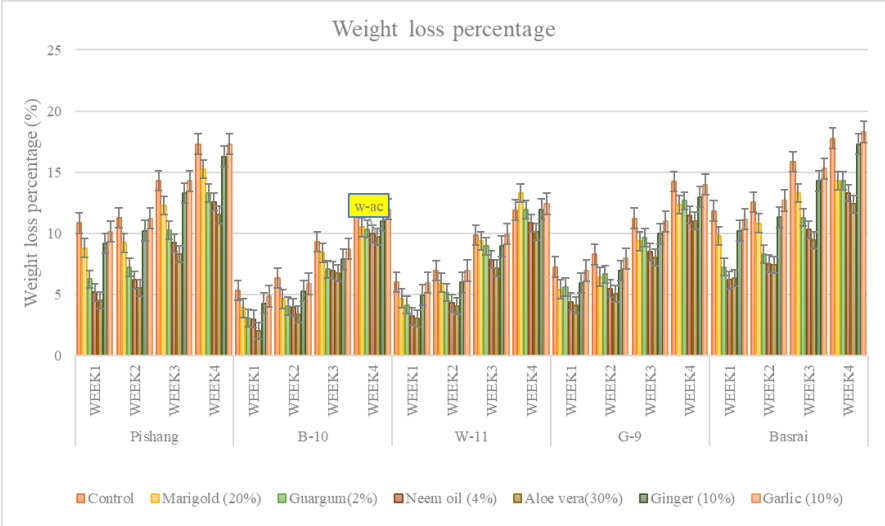

Figure 1. *Weight loss percentage of different banana varieties including V1 Pishang, V2 B-10, V3 W-11, V4 G-9 and V5 Basrai with seven treatments including T1- Control, T2-marigold petals 20%, T3-Guar gum 2% solution, T4-Neem oil 4% solution, T5-Aloe vera 30%, T6-Ginger 10% and T7-Garlic 10% solution show weight loss percentage*

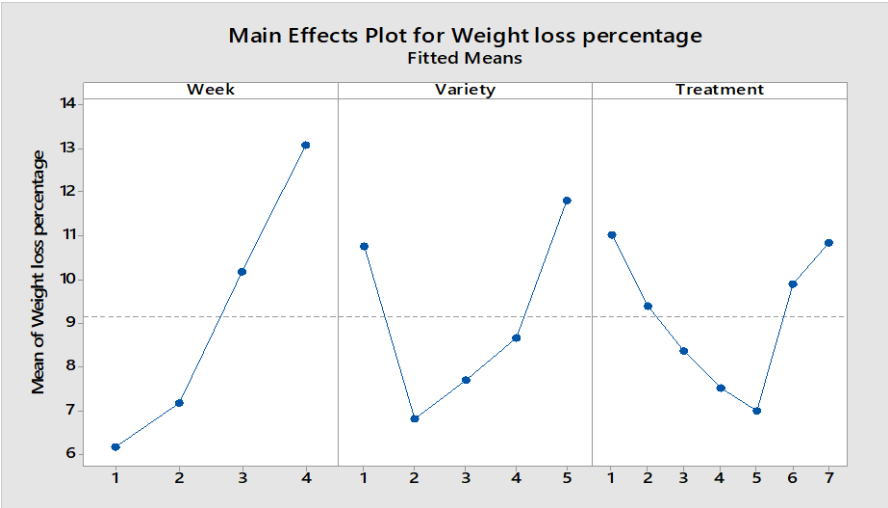

Figure 2. *Main effect plots for weight loss percentage over four weeks are shown, in five banana varieties such as 1-Pishang, 2-Brazilian 10, 3-William 11, 4-Grandnain 9 and 5-Basrai, and 7 treatments include 1-Control, 2-Marigold petals 20%, 3-Guar gum 2% solution, 4-Neem oil 4% solution, 5-Aloe vera 30%, 6-Ginger 10% and 7-Garlic 10% solution*

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It can be stated that weight loss percentage is the basic indicator of any crop or fruit in addressing the best coating treatment for shelf life. Hence it was observed that all the edible coating treatments for shelf-life enhancement significantly reduced weight loss percentage over a period of time. But it was also observed that in the 1st stage *Aloe vera* resulted in the least weight loss percentage among all other treatments. In the past, reduction in weight loss percentage due to different packaging materials were also reported in various studies (Tsegaye, 2020; Getinet et al., 2011; Dadzie and Orchard, 1997). Hailu et al. (2014), observed that the shelf life of Poyo, Giant Cavendish and Williams varieties of banana extended by different packaging treatments showed reduced weight loss percentage.

The different postharvest treatments applied under different storage conditions were observed to have significant impact on the flesh firmness of five different varieties of banana (*Table 3*). Possible reasons for textural softening in banana varieties are due to enzymatic degradation of cell walls (Johnston et al., 2002). In the present study, *Aloe vera* extracts, neem oil extracts, guar gum extracts, as treatments resulted in maximum retention of banana fruit firmness under different storage conditions. The possible reason for maintaining flesh firmness in treated fruits during storages could be due to strong and potent anti-oxidant activities, which serve to prevent membrane deterioration by restricting the lipid peroxidation (Jayachandran, 2007). Likewise, similar type of findings were also reported from the results of different plant extracts' application which increases the fruit firmness during storage by Rammohan et al. (2002) in banana, Jayachandran et al. (2007) in guava and in custard apple by Chouksey et al. (2013).

Firmness

Packaging methods are usually employed to enhance shelf life during transportation which also reduces firmness. In *Figure 3,* it has been observed that the value of firmness within a week gradually decrease to show the banana ripeness. It is demonstrated that the best varieties which show maximum firmness and retain the banana unripen for a long period are Brazilian 10 and William 11. It can also be presumed that treatment five which is *Aloe vera* showed best output to retain the firmness to reduce. So, week 4, B-10 with the treatment of *Aloe vera* show the best outcome considering shelf life of banana. Likewise it was found that the best treatments with packaging material (cling sheet) also reduce rate of firmness in the best varieties. Arnon et al. (2014) observed that firmness of oranges and grapefruit expanded by applying consumable covering of double layers of carboxymethyl cellulose and chitosan. These findings have also been supported by Wang et al. (2013) and Albanese et al. (2007). It is evident that packaging methods are the most critical to enhance shelf-life in banana, likely, as to reduce the rate of firmness slowly in the current best varieties (*Fig.4*).

Skin quality color

For Pishang variety, the mean value of skin quality is the highest throughout the four weeks, however, in terms of weekly observation, marigold, guar gum and ginger enhanced the mean value of skin quality after treatment (*Fig. 5*). At the fourth week high value was observed in control, marigold, guar gum and the lowest value was observed in ginger and garlic treatments. Similarly, in B-10 and W-11, a gradual increase of mean value per week was observed in all treatments as in variety Pishang. Varieties Basrai and G-9 also showed increment in skin quality but lower than that in the rest of the varieties (*Fig. 6*).

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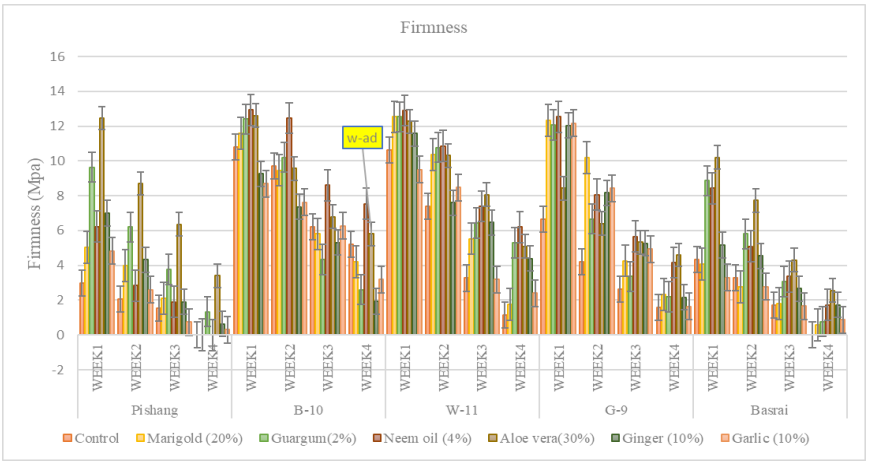

Figure 3. *Firmness of different banana varieties including V1 Pishang, V2 B-10, V3 W-11, V4 G-9 and V5 Basrai with seven treatments such as T1- Control, T2- marigold petals 20%, T3- Guar gum 2% solution, T4- Neem oil 4% solution, T5- Aloe vera 30%, T6- Ginger 10% and T7 -Garlic 10% solution*

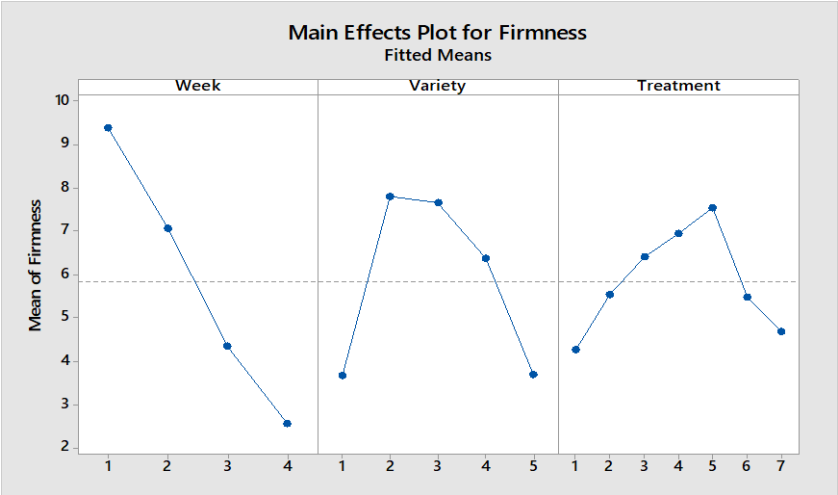

Figure 4. *Main effect plots for firmness through four weeks are shown in five banana varieties including 1-Pishang, 2-Brazilian 10, 3-William 11, 4-Grandnain 9 and 5-Basrai, and 7-treatments as 1-Control, 2-Marigold petals 20%, 3-Guar gum 2% solution, 4-Neem oil 4% solution, 5-Aloe vera 30%, 6-Ginger 10% and 7-Garlic 10% solution*

Quality of skin was evaluated in this study and it was clearly observed that the findings are in agreement to past reports. Treatments employed delayed the progression of skin quality, similar kind of trend was also reported in pomegranate storage (Jiang et al., 2005; Fawole and Opara, 2013).

Taste

In all varieties a constant pattern of gradual enhancement (significant increase $p < 0.05$) in taste was observed by all treatments from week 1 to week 4 (*Fig. 7*; *Table 3*).

In *Figure 8*, it is found that the value of taste within the week gradually increased to show the banana ripeness. In this figure, the best varieties which showed minimum

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value of taste change and retain the banana unripen for a long period were Brazilian 10 and William 11. Treatment five which is *Aloe vera* showed the best results to constrain the firmness to reduce. Consequently, week 4, B-10 with the treatment of *Aloe vera* showed the best results regarding the shelf life of banana.

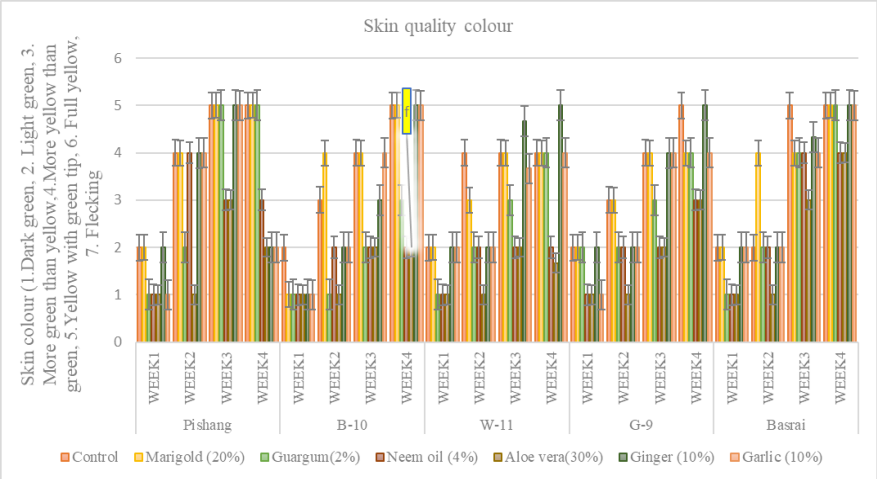

Figure 5. *Skin quality color of different banana varieties including V1 Pishang, V2 B-10, V3 W-11, V4 G-9 and V5 Basrai with seven treatments such as T1-Control, T2-marigold petals 20%, T3-Guar gum 2% solution, T4-Neem oil 4% solution, T5-Aloe vera 30%, T6-Ginger 10% and T7-Garlic 10%*

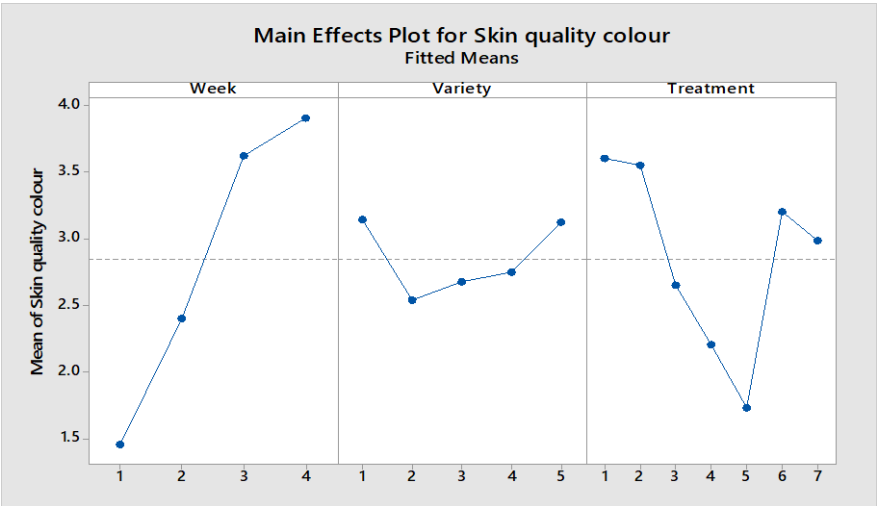

Figure 6. *Main effect plots for skin quality color through four weeks are shown,in five banana varieties like 1-Pishang, 2-Brazilian 10, 3-William 11, 4-Grandnain 9 and 5-Basrai, and 7 treatments including 1-Control, 2-Marigold petals 20%, 3-Guar gum 2% solution, 4-Neem oil 4% solution, 5-Aloe vera 30%, 6-Ginger 10% and 7-Garlic 10% solution*

pH value

The highest values of pH showed in B-10 variety followed by W-11 and G-9 as compared to the rest of the varieties. In case of weekly observation, a gradual increase ($p < 0.05$) of pH values were shown under treatment of *Aloe vera* and neem oil then in

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DOI: http://dx.doi.org/10.15666/aeer/2106_51195140

ginger and garlic in B-10, followed by W-11 and G-9 then in Basrai and Pishang, however the rest of the treatments also showed increase in all varieties with increase of week 1 till week 4 (*Fig. 9; Table 3*).

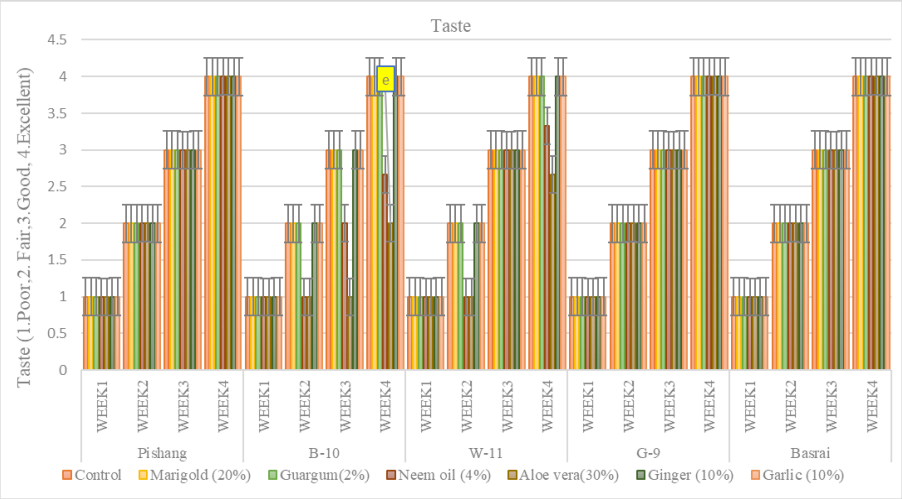

Figure 7. *Taste of different banana varieties including V1 Pishang, V2 B-10, V3 W-11, V4 G-9 and V5 Basrai with seven treatments including T1-Control, T2-marigold petals 20%, T3-Guar gum 2% solution, T4-Neem oil 4% solution, T5-Aloe vera 30%, T6-Ginger 10% and T7-Garlic 10% solution*

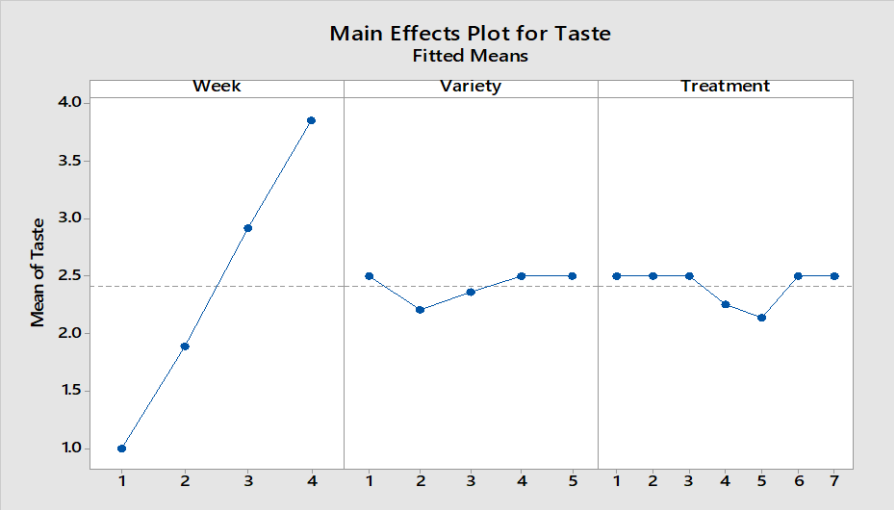

Figure 8. *Main effect plots for taste through four weeks are shown in five banana varieties including 1-Pishang, 2-Brazilian 10, 3-William 11, 4-Grandnain 9 and 5-Basrai, and 7-treatments like 1-Control, 2-Marigold petals 20%, 3-Guar gum 2% solution, 4-Neem oil 4% solution, 5-Aloe vera 30%, 6-Ginger 10% and 7-Garlic 10% solution*

The results of the present study indicated that all the treatments showed highly significant differences on affecting pH value with respect to week interval in selected varieties of banana. Treatments like *Aloe vera* extract, neem oil extract, guar gum extract resulted in the highest pH value among all other treatments, however the gradual increase showed in all treated samples of banana varieties as comparing control.

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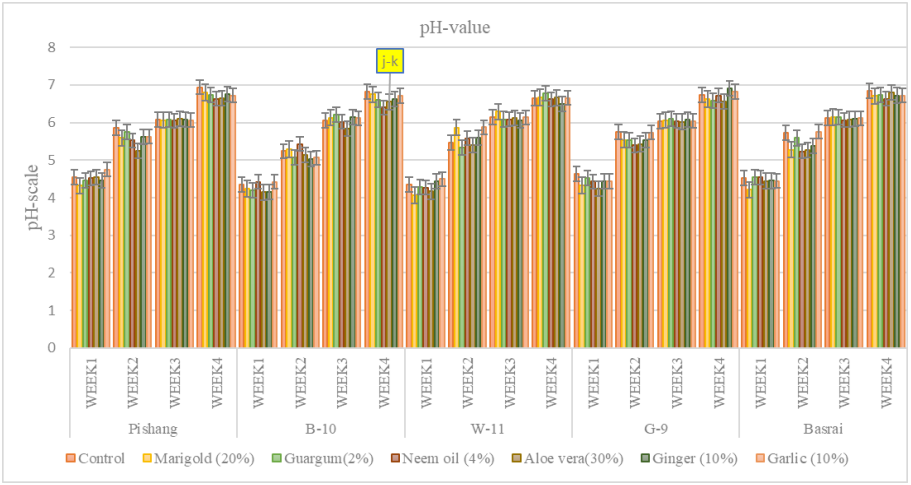

Figure 9. *pH value of different banana varieties including V-1 Pishang, V-2 B-10, V-3 W-11, V-4 G-9 and V-5 Basrai with seven treatments such as T1 is Control, T2 marigold petals 20%, T3 Guar gum 2% solution, T4 Neem oil 4% solution, T5 Aloe vera 30%, T6 Ginger 10% and T7 Garlic 10% solution*

It was clearly observed that the value of pH in every ascending week gradually increased to show the banana ripeness. In this figure, it is described that the best varieties which showed minimum changes in pH value and retained unripened for a long period were Brazilian 10 and William 11. It is further illustrated that treatment five which was *Aloe vera* showed the best results to retain the pH to enhance the shelf life. This means, week 4, B-10 with the treatment of *Aloe vera* showed the best results regarding shelf life of banana.

Turning low in acidity shows capacity which exhibited natural process of senescence. Similarly, the slowdown of pH is related with various reasons; it varies, and may be because of the impact of covering by biochemical state of the foods grown and metabolic movement (Jitareerat et al., 2007). Current results supported the previous findings in which by applying the different edible coating the activity of senescence reduced and the acidity decreased while pH-value increased gradually in all treatments on all five varieties of banana, coating slowed the changes of pH and acidity value by effectively delaying fruit senescence. Several studies also advocated the findings as Garcia et al. (1998). Zhang and Quantick (1998) who reported that acidity value of chitosan or starch-based coated strawberries kept under cold storage decreased with time, but to a lesser extent than that of uncoated fruit. Similarly, the increase in pH-values also supported by previous findings (Elyatem & Kader, 1984; Jitareerat et al. 2007). This could be related with the impact of treatment on the biochemical state of the leafy foods, rate of respiration and metabolism, etc. Likewise, the different type of packaging materials and chemical treatments of gibberellic acid with and without calcium chloride have also found to enhance the pH-value from 4 to 6 with time which ultimately a slow change in enhancing the acidity of the banana varieties (*Fig. 10*). According to Tsegaye (2020), packaging material for banana like polythene bag and carton box found responsible to maintain and enhance the pH-value and titration acidity, too. Several reports are available supporting our results on packaging material maintaining the acidity of banana and slow change in increasing the pH-value (Albertini et al., 2006; Moneruzzaman et al., 2009; Babitha and Kiranmyi, 2010).

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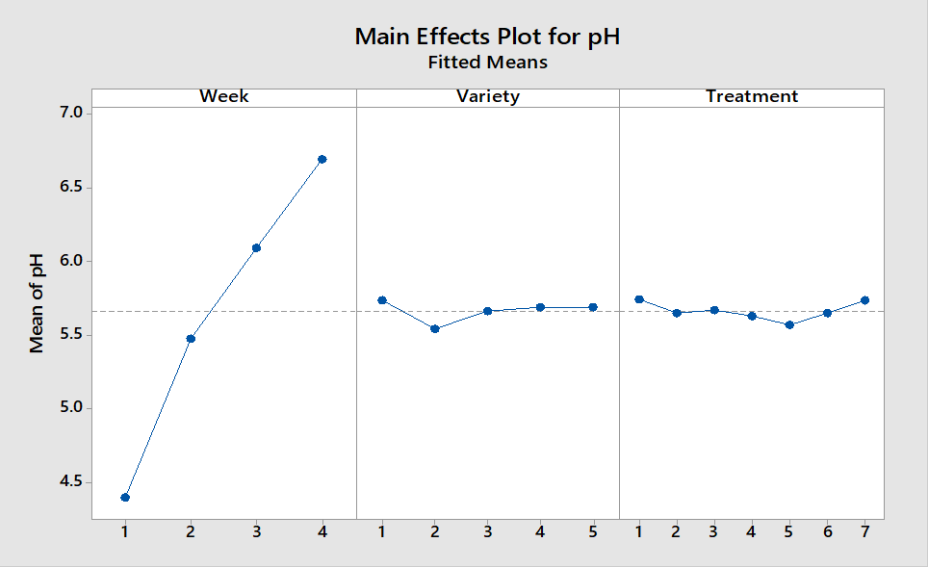

Figure 10. *Main effect plots for pH value through four weeks are shown, five banana varieties viz., 1-Pishang, 2-Brazilian 10, 3-William 11, 4-Grandnain 9 and 5- Basrai, and 7 treatments including 1-Control, 2-Marigold petals 20%, 3-Guar gum 2% solution, 4-Neem oil 4% solution, 5-Aloe vera 30%, 6-Ginger 10% and 7-Garlic 10% solution*

Reducing sugar content

In Pishang, the content of sugar was decreased with increase in weeks. The highest value was recorded in control and garlic treatment in week 1, while a significant decrease observed in sugar content with increase in weeks. Similarly, a same kind of trend was observed in all varieties, hence the highest values of sugar content was observed under garlic treatment in B-10, W-11 at week 4. Further, neem oil treatment also showed moderate decrease in sugar content in G-9 variety (*Fig. 11*). It can be concluded that with the ripening of fruit the reducing sugar decreases with ascending of week days under all 6 treatments. In *Figure 12*, it is shown that the value of reducing sugar content within the week gradually increases to show the banana ripeness. In this figure, the best varieties which showed minimum amount of reducing sugar content and retained unripened for a long periods were Brazilian 10 and William 11. It is evidenced that treatment five which is *Aloe vera* showed the best output in retaining the firmness to retain. Resultantly, week 4, B-10 with the treatment of *Aloe vera* showed the best outcome considering the shelf life of banana.

The reducing sugar content was also observed under various storage conditions. Results suggested that the reducing sugar content enhanced moderately and gently in various edible coating methods for storage of five varieties of banana with respect to 4 weeks. Published literature supported the current findings about the enhancement of sugar content in banana varieties. Wills and Rigney (1979) observed a steady pace expansion in sugar with waxol 6% covered natural products suggested that this was due to waxol influencing the movement of mitochondria and other compounds (Jayachandran et al., 2007; Sharma and Dashora, 2001). Further, the present investigation is also advocated by Passera and Spettoli (1981) in mango, and Iqbal (2022) in banana. Packaging treated material is also helpful to determine reducing sugar content to enhance shelf life, in initially the reducing sugar content increases but

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steadily lower down with the passage of time, however the best treatments showed slow rate of increasing reducing sugar content in best varieties (Stover and Simmond, 1987; Tucker, 1993; Hailu et al., 2014).

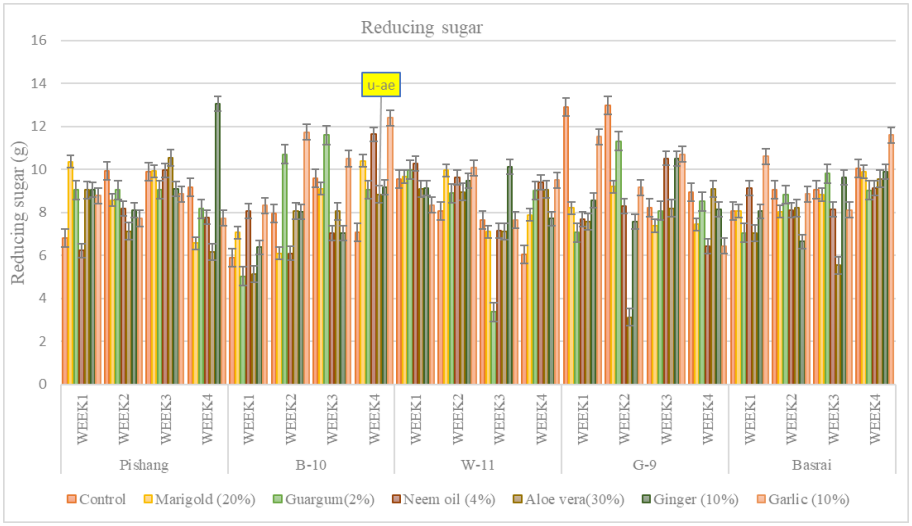

Figure 11. *Reducing sugar content in different banana varieties including V1-Pishang, V2-B-10, V3-W-11, V4-G-9 and V5-Basrai with seven treatments like T1 is Control, T2-marigold petals 20%, T3- Guar gum 2% solution, T4-Neem oil 4% solution, T5- Aloe vera 30%, T6-Ginger 10% and T7- Garlic 10% solution*

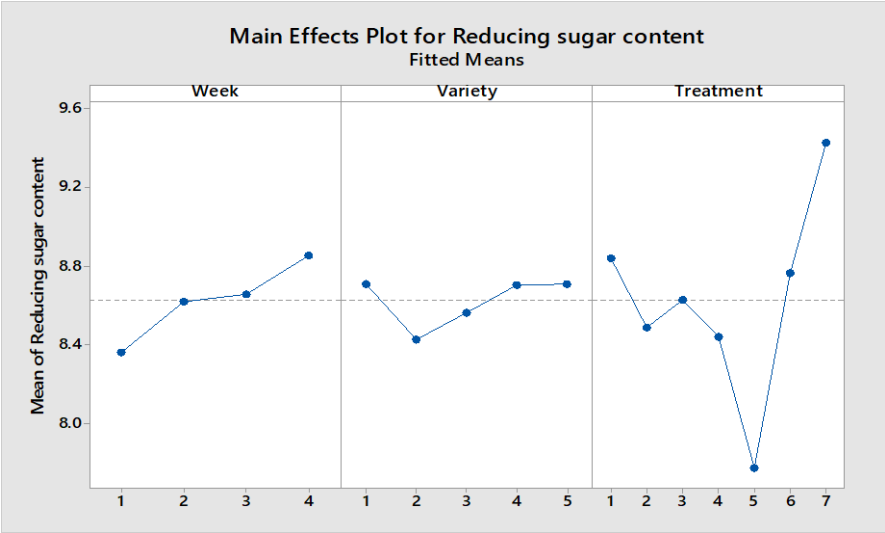

Figure 12. *Main effect plots for reducing sugar content through four weeks are shown, five banana varieties viz., 1-Pishang, 2-Brazilian 10, 3-William 11, 4-Grandnain 9 and 5-Basrai, with 7 treatments including 1-Control, 2-Marigold petals 20%, 3-Guar gum 2% solution, 4-Neem oil 4% solution, 5-Aloe vera 30%, 6-Ginger 10% and 7-Garlic 10% solution*

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Titratable acidity

The acidity value in five varieties of banana was recorded and according to weekly observation, in Pishang, B-10 and W-11, mean values of acidity increased with respect to number of weeks. In the case of Pishang, the highest value of acidity observed in control that gradually increased from week 1 to week 4. In case of treatments *Aloe vera* had high values with gradual increase with week i.e., $p < 0.01$ (*Table 3*). Besides *Aloe vera*, neem oil, marigold had high values. However, the minimum value observed in control, marigold, ginger and garlic treatment at week 4 (*Fig. 13*).

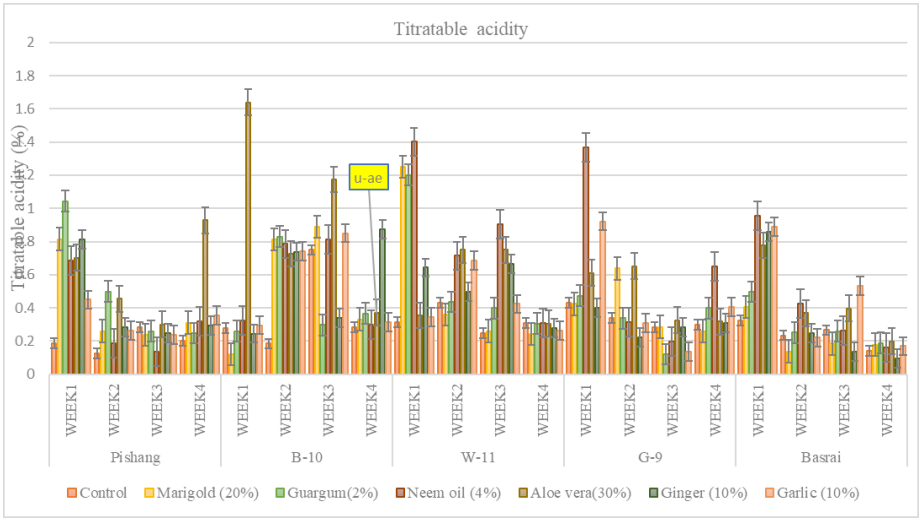

Figure 13. *Ttitratable acidity in different banana varieties including V1-Pishang, V2-B-10, V3-W-11, V4-G-9 and V5-Basrai with seven treatments such as T1 is Control, T2- marigold petals 20%, T3- Guar gum 2% solution, T4- Neem oil 4% solution, T5- Aloe vera 30%, T6- Ginger 10% and T7- Garlic 10% solution*

In Basrai and Pishang, the highest value of acidity was decreased from week 1 to week 4 (*Fig. 13*). The lowest change in acidity was observed in neem oil and *Aloe vera* then ginger, garlic, guar gum and marigold.

In order to compare various banana varieties acidity level it was presented in *Figure 14.* that the value of titratable acidity within the week gradually decreased to show the banana ripeness. This figure shows that the best varieties which showed maximum titratable acidity and retained unripened for a long period were Brazilian 10 and William 11. This figure describes that treatment five which was *Aloe vera* showed the best output in retaining the acidity level to reduce. Therefore, week 4, B-10 with the treatment of *Aloe vera* showed the best outcome regarding shelf life of banana.

The decrease in acidity level showed capacity exhibited by natural process due to senescence. Current results support the previous outcomes in which by applying the different edible coating solutions reduced the activity of senescence and the acidity level slower to decrease and pH-value increase gradually with increase in time (Jitareerat et al., 2007).

In the five varieties the low change in protein content was recorded from week 1 to week 4. In the case of treatments, the highest protein content in Basrai was recorded in control then marigold followed by guar gum, ginger in week 1, likewise, in week 2 and

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3. However, in week 4 *Aloe vera* showed the lowest mean value of protein content in B-10 variety as compared to the rest of the treatments (*Fig. 13*).

The lowest value of protein content among all varieties under treatments was observed in Basrai-10 variety in week 1-week 4 under *Aloe vera* treatment, since it was reduced with the passage of time. In the case of Basrai, marigold, guar gum and garlic treatments showed high protein content in week 1, week 2 and week 4 (*Fig. 14*).

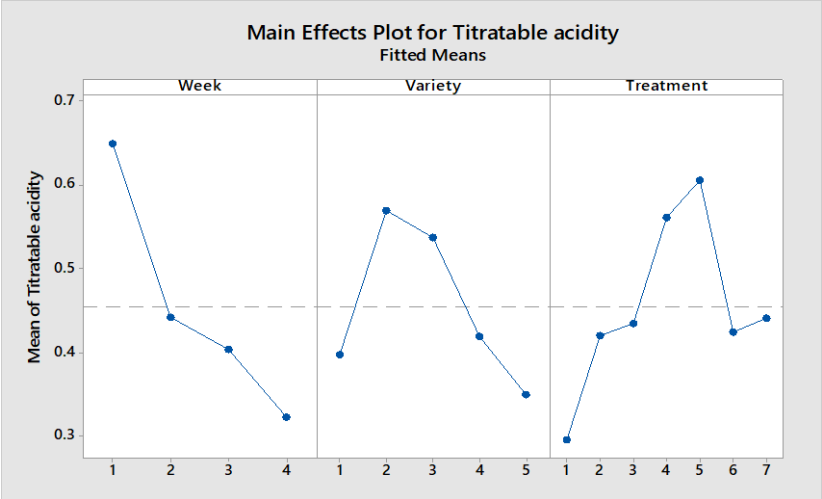

Figure 14. *Main effect plots for reducing sugar content through four weeks are shown, five banana varieties including 1-Pishang, 2-Brazilian 10, 3-William 11, 4-Grandnain 9 and 5-Basrai, and 7-treatments viz., 1-Control, 2-Marigold petals 20%, 3-Guar gum 2% solution, 4-Neem oil 4% solution, 5-Aloe vera 30%, 6-Ginger 10% and 7-Garlic 10% solution*

Protein estimation

In *Figure 15*, the best variety which showed minimum protein value change and retain the banana unripening for long period such as in variety 2 and 3 which are Brazilian 10 and William 11. It can be deduced that treatment five which was *Aloe vera* showed the best output in retaining the protein content. So, in week 4, B-10 with the treatment of *Aloe vera* showed the best outcome regarding shelf life of banana. In *Figure 16*, it can be clearly observed that the value of protein content within the week gradually increased in a very low level to show the banana ripeness.

Protein content in order to enhance shelf-life banana varieties were evaluated under post-harvest techniques, hence our results indicated that content of protein remains stable and very little change was observed throughout the four weeks of shelf-life by applying edible coating as well as packaging material methods. Although few reports are available conducted on protein content during post-harvest including banana during ripening period which support current findings (Wade et al. (1972, 1978). It was found that there was a consistency in protein as well as amino acid content in banana pulp during the ripening period. Moreover, such type of findings were also reported on apple and tomato with respect to protein content (Galliard, 1968; Karla et al., 2013).

Total soluble solids

It was observed that in all five varieties i.e., Pishang, B-10, W-11, G-9 and Basrai the mean values of TSS were gradually increased from week 1 to week 4 (*Fig. 17*). The

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most effective treatments that decreased the TSS values in all varieties were *Aloe vera*, neem oil, guar gum, ginger garlic and the least effective was marigold.

In *Figure 18*, it can be clearly observed that the value of total soluble solids within the week gradually increased to show the banana ripeness. The best variety which show minimum amount of total soluble solids and retained unripen for a long period was variety 2 which is Brazilian 10. It can be concluded that treatment five which was *Aloe vera* showed the best output in retaining the total soluble solids to reduce. So, week 4, B-10 with the treatment of *Aloe vera* showed the best outcome considering shelf life of banana.

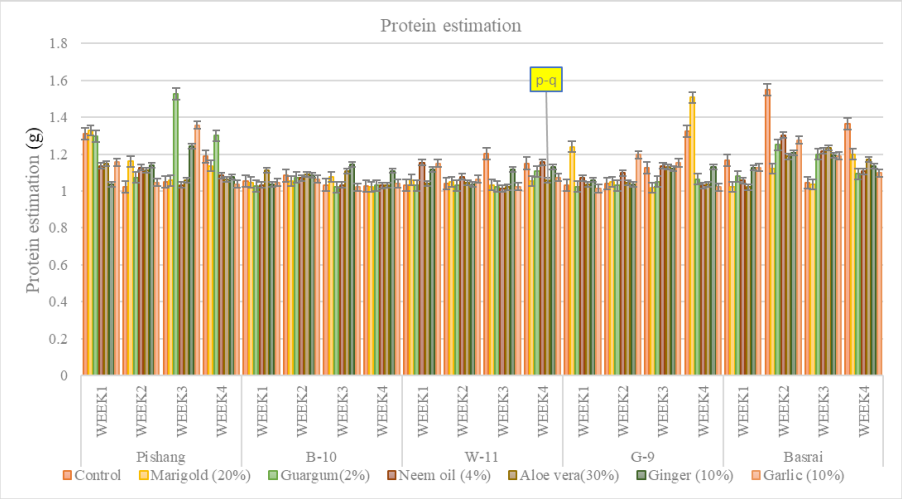

Figure 15. *Protein estimation of different banana varieties including V1-Pishang, V2-B-10, V3-W-11, V4-G-9 and V5-Basrai with seven treatments viz., T1 is Control, T2-marigold petals 20%, T3-Guar gum 2% solution, T4-Neem oil 4% solution, T5-Aloe vera 30%, T6-Ginger 10% and T7-Garlic 10% solution*

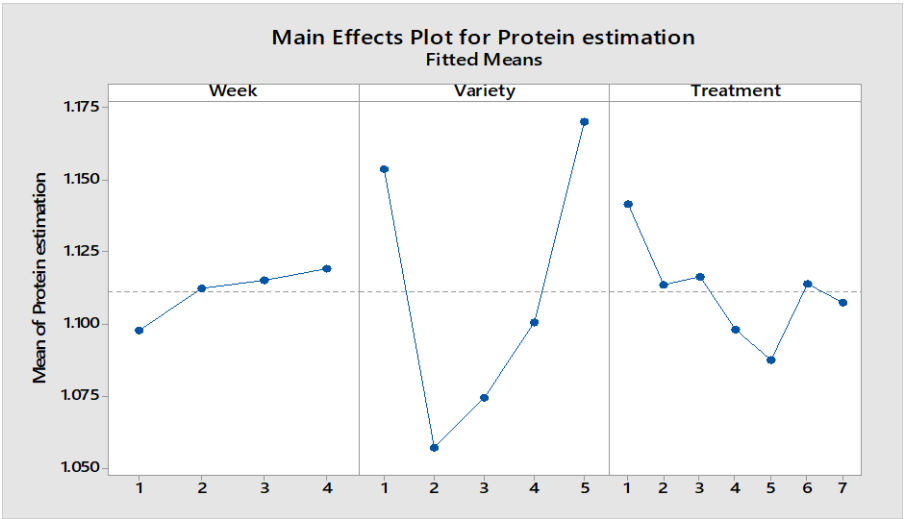

Figure 16. *Main effect plots for protein estimation through four weeks are shown, five banana varieties viz., 1-Pishang, 2-Brazilian 10, 3-William 11, 4-Grandnain 9 and 5-Basrai, and 7 treatments including 1-Control, 2-Marigold petals 20%, 3-Guar gum 2% solution, 4-Neem oil 4% solution, 5-Aloe vera 30%, 6-Ginger 10% and 7-Garlic 10% solution*

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It was observed that different edible coating has been improved the quantity of TSS with time, similar type of results were also reported on different varieties of banana, mango and tomato with edible coating treatment (Kittur et al., 2001; Ruelas-Chacon et al., 2017; Mohammed et al., 2021). In the case of edible coating solutions with packaging treatments, the TSS values pronouncedly slowly increased with passage of time in best varieties were observed (Abdullah et al., 2016; Tsegaye, 2020). The reason is suggested to be that decline in respiration and metabolic rate can increase the TSS value in different packaging treatments as described by Awoke et al. (2012).

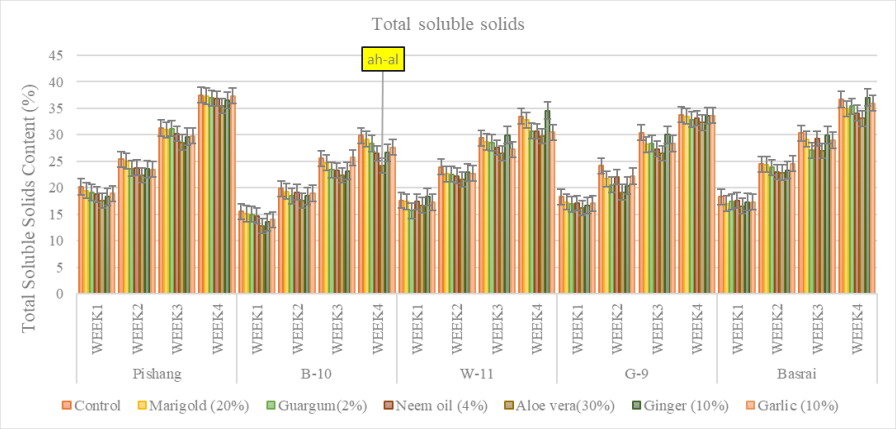

Figure 17. *Total soluble solids in different banana varieties including V1-Pishang, V2-B-10, V3-W-11, V4-G-9 and V5-Basrai with seven treatments such as T1 is Control, T2-marigold petals 20%, T3-Guar gum 2% solution, T4-Neem oil 4% solution, T5-Aloe vera 30%, T6-Ginger 10% and T7-Garlic 10% solution*

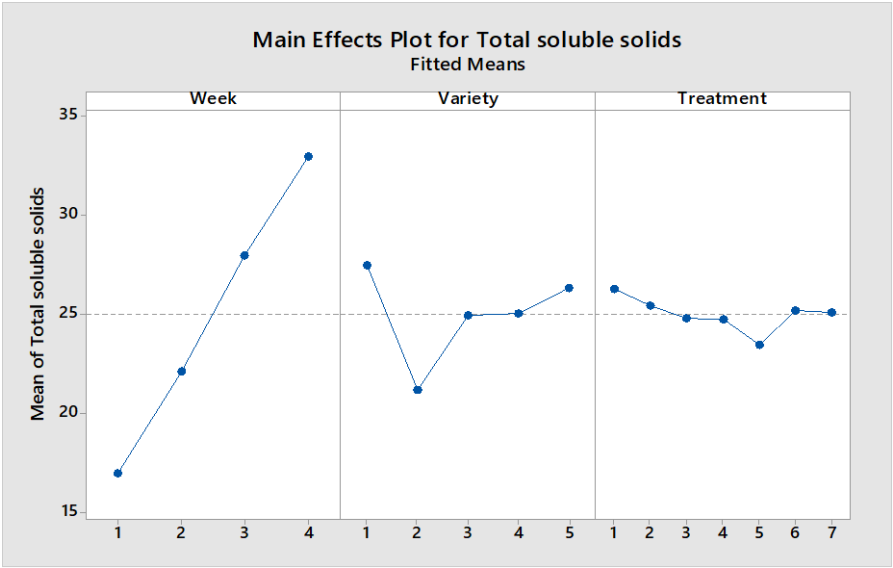

Figure 18. *Main effect plots for total soluble solids through four weeks are shown, five banana varieties viz., 1-Pishang, 2-Brazilian 10, 3-William 11, 4-Grandnain 9 and 5-Basrai, and 7-treatments including 1-Control, 2-Marigold petals 20%, 3-Guar gum 2% solution, 4-Neem oil 4% solution, 5-Aloe vera 30%, 6-Ginger 10% and 7-Garlic 10% solution*

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Table 3. *ANOVA represents Mean squares (MS) for treatments; weight loss percentage, firmness, skin quality color, taste, pH, reducing sugar content, titratable acidity, protein estimation and total soluble solids parameters of banana*

Source of variance	DF	Weight loss percentage	Firmness	Skin quality color	Taste	pH	Reducing sugar content	Titratable acidity	Protein estimation	Total soluble solids
Week	3	1030.82***	951.715***	134.625***	160.440***	101.206***	4.3547***	2.02856***	0.009156*	5059.24***
Variety	4	366.28***	352.114***	6.220***	1.474***	0.439***	1.3358***	0.74901***	0.203646***	471.06***
Treatment	6	149.49***	85.152***	29.021***	1.426***	0.217***	14.8929***	0.61812***	0.017137***	44.02***
Week*variety	12	0.59***	8.868***	4.206***	0.274***	0.167***	21.5110***	0.47197***	0.054699***	21.52***
Week* Treatment	18	0.27***	4.064***	2.215***	0.207***	0.062***	4.9599***	0.12113***	0.027372***	1.76***
Variety* Treatment	24	7.26**	17.202***	0.876***	0.647***	0.030***	7.7894***	0.14841***	0.031922***	2.67***
Week*Variety*Treatment	72	0.30***	3.179***	1.056***	0.131***	0.041***	7.5724***	0.17606***	0.021146***	1.39***
Error	280	0.13***	0.109***	0.010***	0.007***	0.469***	0.0618***	0.00316***	0.003099***	0.33***
Total	419									

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Conclusion

As far as edible coating solutions application to enhance shelf life is concerned, it was observed that *Aloe vera* treatment resulted in a significantly enhanced shelf life of banana among all treatments in all four weeks. In this series *Aloe vera*, Neem oil, Guar Gum mostly show affirmative results in all aspects that were observed during the experiment. While in the case of packaging material, cling sheet packaging material exhibited commendable results in all three stages of experiments.

Recommendations

In the southern parts of the country especially Sindh, Basrai variety is cultivated at large scale which can be substituted with B-10 as it stays about 4 weeks in summer season. *Aloe vera* gel spray at the lowest normal temperature of cold storage houses is hereby recommended for large scale cultivation. Furthermore, *Aloe vera* proved the best treatment to enhance the shelf life of banana along with cling sheet packaging material. This *Aloe vera* gel spray solution is also recommended to overcome the economic losses of banana as well as other fruit losses during post-harvest management in cold houses, too.

Acknowledgments. We acknowledge Dr. Dost Mohammad Kaloi, Director, Thatta Institute of Sugarcane and Horticultural Crops, for providing banana samples. Authors are also grateful to Dr. Zahoor Ahmad, Chairperson, Department of Statistics, University of Gujrat, Gujrat, Pakistan for statistical analysis.

Conflict of interests. The authors declare no conflicts of interests.

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