OPEN ACCESS Freely available online

ISSN: 2168-9881
Agrotechnology

Research Article

Effect of Different Edible Oil Coating and Storage Life on Post-Harvest Quality of Banana Fruit

Muhammad Asghar, Abdul Mateen Khattak, Waqas Habib, Shahbaz Ahmad, Manzoor Ahmed, Ahmad Farooq*

Department of Horticulture, The University of Agriculture, Peshawar, Pakistan

ABSTRACT

An experiment was carried out to study the "Effect of different edible oil coating and storage life on post-harvest quality of banana fruit" at Post harvest Laboratory, Department of Horticulture, the University of Agriculture Peshawar Pakistan during the year 2021. Banana fruit CV, Cavendish was obtained from local market Peshawar brought from Hyderabad during the month of April 2021 at physiological mature stage. The experiment was laid out using Completely Randomized Design (CRD) with two factors repeated two times. The fruits were then kept in packaging materials with one apple per bunch. When the fruits were ripened were divided into two groups, one group was coated with edible oil (olive, coconut and butter) and the other is storage life (0,3,6,9,12) and kept at room temperature 260C at RH 90%-95% for 12 days. The data regarding banana fruits coated with butter oil showed maximum fruit firmness, titratable acidity, ascorbic acid content, fruit color score, fruit taste score and fruit decay percentage. The maximum TSS was observed in banana fruit coated with olive oil. Regarding the other mean for storage duration maximum fruit firmness, minimum fruit decay and minimum TSS was recorded in freshly ripened banana fruits. While maximum test score, and color score observed in fruits stored for 12 days. Most of the studied attributes were significantly affected by T × SD interaction. It is concluded from the present results that banana fruits harvested at physiological maturity ripened under natural ripening agent i.e. apple, coated with butter oil retained most of the quality attributes for 12 days, is recommended for better shelf life and consumer preferences.

Keywords: Edible coating; Post-harvest; Storage life; Banana fruit; *Musa paradidica*

INTRODUCTION

Banana (*Musa paradidica L.*) belongs to family Musaceae. Banana is an edible fruit produced by several kinds of large herbaceous flowering plants in the genus Musa [1]. Banana evolved in the humid tropical regions of South East Asia with India as one of its centers of origin. Modern edible varieties have evolved from the two species-Musa acuminata and Musa balbisiana and their natural hybrids, originally found in the rain forests of South East Asia. During the 17th century AD its cultivation spread to Egypt and Africa. At present banana is being cultivated throughout the warm tropical regions of the world between 300 N and 300 S of the equator [2]. Bananas are predominantly produced in Asia, Latin America and Africa. The biggest producers are India and China which produces 29 million and 11 million tons per year respectively. Production in both countries mostly serves the domestic market. Other large producers are Philippines Ecuador and Brazil. About 113.21 million tons bananas are produced worldwide per year [3]. Approximately 5.6 million hectares of land is dedicated to banana production globally. The rapid expansion of the banana industry is evident in the evolution of the harvested area over time, which amounted to 3.6 million hectares in 1993 and 4.6 million hectares in 2000 [4]. In 2017-2018, the total area of Pakistan under banana cultivation was 30.1 thousand hectares with an average production of 135.1 thousand tones. The area under banana cultivation in Punjab is

Correspondence to: Ahmad Farooq, Department of Horticulture, The University of Agriculture, Peshawar, Pakistan, E-mail: farooqwazir61@gmail.com

Received: 15-Feb-2024, Manuscript No. AGT-24-24905; **Editor assigned:** 19-Feb-2024, PreQC No. AGT-24-24905; **Reviewed:** 04-Mar-2024, QC No. AGT-24-24905; **Revised:** 11-Mar-2024, Manuscript No. AGT-24-24905; **Published:** 18-Mar-2024, DOI:10.35248/2168-9891.24.13.356

Citation: Asghar M, Khattak AM, Habib W, Ahmad S, Ahmad M, Farooq A (2024) Effect of Different Edible Oil Coating and Storage Life on Post-Harvest Quality of Banana Fruit. Agrotechnology. 13:356.

0.2 thousand hectares, Sindh 28.1, KPK 0.7 and Baluchistan 1.1 thousand hectares with a total production of banana is 0.9, 109.5, 13 11.7 thousand tones respectively [5]. Moreover, edible coatings, which intend to reduce ripening processes and protect the fruit from water loss and spoilage, may be a good way to enhance the shelf life of the products. More recently, the inclusion of additives into these edible coatings to increase their effectiveness, such as essential oils and their constituents with antimicrobial and antioxidant activities, has been reported and patented [6]. Different edible oil like coconut, olive, butter, custard, paraffin, and so on, is used for coating fruits and vegetables [7]. The importance of natural ripening agent, banana (both commercially and nutritionally) and problems related to reduce shelf life and quality. The use of edible coating can reduce the respiration rate and retain the quality of banana.

MATERIALS AND METHODS

Experimental site and plant material

The experiment was carried out to study the Effect of different edible oil coating and storage life on post-harvest quality of banana fruit ripened under natural ripening agent apple at the Department of Horticulture, The University of Agriculture Peshawar Pakistan, during the year 2022. Banana fruit cv. Cavendish was obtained from Peshawar local market brought from Hyderabad during the month of January 2022 at physiological maturity stage.

Experimental design and treatment combination

The experiment was laid out using Completely Randomized Design (CRD) with two factors repeated two times. Banana fruits were taken at physiological maturity from local market Peshawar and kept in cotton crates and treated with edible oil and kept at room temperature 26°Cat RH 90%-95% for 12 days. Data were collected after 3 days of interval.

Treatment with ripening agent apple

Banana fruits were carefully transported to the storage in wooden boxes. The injured and bruised fruit were discarded. The fruit were washed in running tape water and then dried. Data on qualitative attributes were recorded before and after ripening, about 168 fruits of banana at physiological maturity from the whole fruits were taken and ripened under polyethylene with 130 gm apple without slices in each bunch (12) of banana. After ripening of banana apples were removed from packaging materials.

Preparation of edible oil

Edible oil was taken from local market Board bazar Peshawar with 100% purity. Twenty four ml olive oil was coated on 12 bananas and each banana was coated completely with 2 ml by cotton. Similar procedure was carried out for coating banana fruits with coconut and butter oil.

Studied parameters

Fruit firmness (kgcm^{-2}) (determined by with the help of penetrometer), Total soluble solids (°Brix) (using a standard method of Association of Official Agricultural Chemists (AOAC) (2012) using an Abbe refractometer), Titratable acidity (%) (Determined using the titrimetric method as described in AOAC (2012), Ascorbic acid (Vitamin C) (titrimetric method as described in AOAC (2012), Weight loss (using a high-performance balance), Decay percentage (%) (Calculated by following formula using Decay percentage=(number of rotten fruits)/(Total number of fruits) × 100), Taste (through visual observation and give numbers to fruit on the basis of taste), Colour (through visual observation and give numbers to fruit on the basis of color).

Statistical analysis

The data collected on various attributes were analyzed using Completely Randomized Design (CRD) using statistical software 8.1. In case, the data was significant, Least Significant Difference test (LSD) was applied for mean comparison [8].

RESULTS

The experiment was performed to assess the Effect of different edible oil coating and storage life on post-harvest quality of banana fruit. The data of all the experimental parameters were recorded. The results have been mentioned and discussed, and the following sections provide potential explanations.

Firmness (Kg cm^{-2})

The data relating to firmness are present in Table 1. Statistical analyses show that there were significant differences among the edible coating as well as storage life in term of fruit firmness. The interaction between edible coating and storage life was significant. The mean data showed that banana fruits coated with butter oil recorded the highest firmness (3.29 Kg cm^{-2}), and the lowest firmness (2.80 Kg cm^{-2}) recorded in banana fruit coated with olive oil. The mean for storage duration maximum firmness was found in fresh ripened fruit (4.00 Kg cm^{-2}) while minimum firmness was found (1.86 Kg cm^{-2}) after 12 days. The treatment and storage duration interaction (T × SD) showed that the highest firmness (3.85 Kg cm^{-2}) was observed in banana fruits coated with butter oil for 3 days and the lowest firmness was recorded in banana fruits untreated with coating materials stored for 12 days.

According to mean the firmness was gradually decreases as storage interval increases in both treated and untreated treatments. At the end control clearly shows the lowest firmness. The retention of firmness can be explained by retarded degradation insoluble protections to the more soluble pectic acid and pectin. During fruit ripening depolymerization or shortening of chain length of pectin substances occurs within increase pectin sterase and polygalactronase activities [9]. Low oxygen and high carbon dioxide concentration reduce the activities of these enzymes and allow retention of the firmness during storage [10]. Application of coating reduced the respiration rate of fruits after its harvest, due to which less catabolic works happens and maintains the decrease in firmness [11]. Our result greatly reflects the result of Anany et al. [12]. Edible coating significantly retained the firmness of Anna apple *Malus domestica Borkh.*

Total Soluble Solids (TSS °brix)

The mean data regarding TSS of banana is shown in Table 1. Statistical analyses show that there were significant differences among the edible coating as well as storage life in term of TSS. However the interaction between edible coating and storage life was non-significant. The mean data show that banana fruit coated with olive oil recorded maximum TSS (26.19 °brix) which was followed by TSS (25.89 °brix) in banana fruits coated with coconut oil and while lowest TSS (25.49 °brix) was observed in banana fruits coated with butter oil. The mean for storage duration the highest TSS (27.03 °brix) was recorded in banana fruits stored for 12 days and minimum TSS (24.00 °brix) was observed in freshly harvested banana after ripening.

It is evident from the mean table that maximum total soluble solids was recorded in fruit stored for 12 days while the minimum total soluble solids was recorded in freshly harvested fruits. Khan et al. reported that increase in the TSS of citrus fruits is mainly due to the breakdown of complex carbohydrates into sugar and low moisture content of the fruit also found increase in Total Soluble Solids (TSS) level in all three treatments from day 1 to day 5 [13,14]. On 5th day the total soluble solids (TSS) was significantly higher than on 1st day, thus, genetic makeup of fruit plays major role in increasing Total Soluble Solids (TSS) day by day. Further more rapid increase in TSS due to higher rate of cell metabolism which results reduction in total acidity by concerting different acids into sugars. Soften the fruits and thus leads to faster senescence process. Thus, our result reflects the result of that TSS has been slowly increased in mango fruits coated with butter oil compared to other treatment [15].

Titrate acidity (%)

The mean data regarding titrate acidity of banana is shown in Table 1. Statistical analyses show that there were significant differences among the edible coating as well as storage life in term of titrate acidity. However the interaction between edible coating and storage life was non-significant. The mean data showed that Banana fruits coated with butter oil significantly retained highest TA (0.28%) which significantly similar with TA (0.25%) in banana fruits coated with coconut oil, and the minimum TA is recorded in banana fruit coated with olive oil. Concerning the mean data for storage duration the maximum titrate acidity (0.32%) was recorded in freshly harvested ripened banana fruits while the minimum titratable acidity (0.17%) was observed in Banana fruits stored for 12 days.

The results show that the titrate acidity values were gradually and significantly decreased with increasing storage duration. The untreated sample had the lowest level of titrate acidity at the end of storage period, while other treatments have high than control. Since organic acids such as malic or citric acid are primary substances for respiration, a reduction in acidity and hence an increasing pH are expected in highly respiring fruits. Coating may reduce respiration rates and may, therefore delay the utilization of organic acids [9]. So our results best reflects the results of Anany et al., [12].

Ascorbic acid (mg/100 gm)

The data relating to ascorbic acid are present in Table 1. Statistical analyses show that there were significant differences among the edible coating as well as storage life in term of ascorbic acid. The interaction between edible coating and storage life was significant. The mean data showed that maximum Ascorbic acid (4.86 mg/100 gm) was observed in banana fruits coated with butter oil and the minimum Ascorbic acid (3.66 mg/100 gm) was recorded in banana fruit treated with olive oil. Regarding the mean for storage duration the highest Ascorbic acid (6.00 mg/100 gm) was observed in banana in freshly harvest ripened fruits and the lowest ascorbic acid (2.92 mg/100 gm) was recorded in Banana fruits stored for 12 days. The (T × SD) interaction showed that highest Ascorbic acid (6.00 mg/100 gm.) was found in freshly harvest ripened banana fruits and the lowest Ascorbic acid (0.60 mg/100 gm) was found in banana fruits stored for 12 days.

Our results show that Ascorbic acid content was high in fresh fruits then those of last storage. Also coating has control the Vitamin C content up to some extent, the best result was fruits coated with butter oil, and worst result was the fruits uncoated and unpacked.

Ascorbic acid is water soluble and for that reason it is depleted with the moisture loss. Castor oil coating retains ascorbic acid content by reducing water loss and retarding ripening process. Castor oil also adhere antioxidants which inhibits oxidation of the fruit and as a result retains the ascorbic acid content of fruit [16]. So our result is in best agreement with the results of Shah et al., that maximum Ascorbic acid was found in plum fruits coated castor oil then all other treatments including control [17]. Influence of edible coating and storage duration on post-harvest performance of plum.

Table 1: Firmness (kgcm^{-2}), Total soluble solid (TSS brix), Titrate acidity (%) and Ascorbic acid (mg/100 gm) of banana fruit as affected by edible oil coating and storage life.

Treatment	Attributes			
Storage time (m)	Firmness (Kg cm^{-2})	Total Soluble Solids (TSS °brix)	Titrate acidity (%)	Ascorbic acid (mg/100 gm)
0	4	24	0.32	6
3	3.51	25.51	0.29	5
6	3.11	26.11	0.26	3.73

9	2.59	26.63	0.23	3.64
12	1.86	27.03	0.19	2.92
LSD (P ≤ 5%)	0.16*	0.22*	0.017*	0.23*
Coating oils				
Olive oil	2.8	26.19	0.24	3.66
Coconut oil	2.95	25.89	0.25	4.25
Butter oil	3.29	25.49	0.28	4.86
LSD (P ≤ 5%)	0.13*	0.18*	0.014*	0.2*
Interaction storage time × coating oil	*	NS	NS	*
Note: "*"- LSD (Least Significant Difference)				

Weight loss (%)

The data relating to weight loss are present in Table 2. Statistical analyses show that there were significant differences among the edible coating as well as storage life in term of fruit weight loss. The interaction between edible coating and storage life was significant. The mean data showed that maximum weight loss (5.05%) was recorded in of banana fruit coated with olive oil, which was followed by weight loss (4.56%) in banana fruits treated with coconut oil. The lowest weight loss (3.79%) was observed in Banana fruits coated with butter oil. Regarding the mean data for storage duration the highest weight loss (9.3%) was recorded in banana fruits stored for 12 days. The lowest weight loss (2.52) was observed in banana fruits stored for 3 days. Regarding the T × SD interaction, more weight loss (11.66%) was recorded in banana fruits untreated with coating materials stored for 12 days while less weight loss (1.77%) was observed in Banana fruits coated with butter oil stored for 3 days.

The primary mechanism of moisture loss from fresh fruits and vegetables is by vapour phase diffusion driven by a gradient of water vapour pressure at different locations. [9]. On the other hand, respirations cause a weight reduction because a carbon atom is lost from the fruit in each cycle [18]. Wax coating decrease the rate of respiration and transpiration which resulted in reduced weight loss upto 65% compared to control sample in apple cv. Tsugaru [19]. Weight loss in control was high due to high rate of transpiration and respiration as compared to wax treated samples. This is because of the barrier that is provided by the wax coating between inner and outer environment of the fruits and hence maintain the weight of the fruits throughout the storage [20].

So our result is in agreement with the finding of that butter oil coating has antioxidant and hydrophobic properties and hence significantly retained the weight loss in mango [7].

Decay percentage (%)

The data relating to decay percentage are present in Table 2. Statistical analyses show that there were significant differences among the edible oil coating as well as storage life in term of fruit weight loss. The interaction between edible oil coating and storage life was significant. The mean showed that highest fruit decay (5.41%) was recorded in Banana fruit coated with olive oil, which was followed by fruit decay (3.33%) in banana fruits coated with coconut oil. The lowest fruit decay (0.00%) was observed in Banana fruits coated with butter oil. Regarding the mean for storage duration the highest fruit decay (11.10%) was recorded in banana fruits stored for 12 days. The lowest fruit decay (0.00) was observed in freshly harvest ripened banana. Regarding the T × SD interaction more fruit decay (25.00%) was recorded in Banana fruits untreated with coating materials and stored for 12 days.

The results show that no decay sign were observed after 6 day after the beginning of storage period. Coating significantly reduced percent decay compared to control sample without coating during the storage period.

Decay percentage of the control at the end of storage period was highest then decay percentage of fruits coated with butter oil. The decrease in decay percent of treated sample was probably due to the effect of these coating and packaging on delaying senescence, which allowed the commodity more vulnerable to pathogenic infection as a result of loss of cellular or tissue integrity [21]. Our result is in agreement with who observed that edible oil coating prevented the fruits (Anna apple) from decay [12].

Taste

The data relating to taste are present in Table 2. Statistical analyses show that there were significant differences among the edible oil coating as well as storage life in term of fruit taste. The interaction between edible oil coating and storage life was significant. The mean showed that highest taste score (7.8) was recorded in Banana fruits coated with butter oil. The lowest taste score (6.6) was observed in Banana fruits in olive oil. According to the mean for storage duration the highest taste score (7.67) was recorded in banana fruits stored for 12 days. The lowest taste score (6.00) was observed in banana fruits in freshly harvested ripened fruits. Regarding the (T × SD) interaction, more taste score (9.00) was recorded in Banana fruits treated with butter oil coating and closely followed (9.00) stored for 12 days.

During storage duration also maximum taste recorded in fruits stored for 12 days while the minimum was recorded in freshly harvested fruits. They are synthesized in the cytosol and localized in vacuoles and synthesized *via* the phenylpropanoid pathway. Two classes of genes are required for anthocyanin biosynthesis, the structural genes encoding the enzymes that directly participate in the formation of anthocyanin and other flavonoids and the regulatory genes that control the transcription of structural genes. It has been reported that ethylene is involved in regulation of genes related to anthocyanin biosynthesis [22]. Astringency which arises due to tannins in fruits shows a decreasing trend during ripening of many fruits. It is reported that astringency depends on the molecular structure of tannin which determines cross linking with proteins and glycoproteins [23]. Therefore tannins give astringent taste when they are dissolved in saliva. An increase in the molecular weight of tannin by polymerization which occurs during ripening causes a lack of astringency due to the insolubility of tannins [24]. Our result show that best taste was found in Banana fruits coated with butter oil. So our result is in best agreement with the results of Shah et al., that best taste score was found in plum fruits coated castor oil then all other treatments including control.

Color

The data relating to color are present in Table 2. Statistical analyses show that there were significant differences among the edible oil coating as well as storage life in term of fruit color. The interaction between edible oil coating and storage life was significant. The mean showed that maximum color score (7.3) was recorded in banana fruits coated with butter oil and the minimum color score (6.00) was observed in banana fruits coated with coconut oil. The mean for storage duration the highest color score (7.66) was recorded in banana fruits stored for 12 days. The lowest color score (4.00) was observed in freshly harvest ripened banana fruits. Concerning the interaction and storage duration (T × SD), more color score (9.00) was recorded in banana fruits treated with butter oil closely followed by (9.00) stored for 12 days while least Color score (4.00) was observed in freshly harvest ripened banana fruits.

During storage duration also maximum color recorded in fruits stored for 12 days while the minimum was recorded in freshly harvested fruits Color development is an important maturity index of many fruits and associated with ripening. In many cases the color change during fruit ripening is due to the unmasking of preexisting pigments by degradation of chlorophylls and synthesis of anthocyanin and carotenoids. Carotenoid biosynthesis during ripening has been studied using tomato plant as a model. Carotenoids are derived from terpenoids and are synthesized in fruit at a high rate during the transition from chloroplast to chromoplast [25]. Anthocyanins are responsible for orange, red, pink, blue and purple colours in fruits and can be classified in to two groups as flavonoids and phenolic compounds [14]. They are synthesized in the cytosol and localized in vacuoles and synthesized *via* the phenylpropanoid pathway. Two classes of genes are required for anthocyanin biosynthesis, the structural genes encoding the enzymes that directly participate in the formation of anthocyanin and other flavonoids and the regulatory genes that control the transcription of structural genes. It has been reported that ethylene is involved in regulation of genes related to anthocyanin biosynthesis [21,26]. Our result show that best color was found in banana fruits coated with butter oil. So our result is in best agreement with the results of Shah et al. that best color score was found in plum fruits coated castor oil then all other treatments including control [16]. Influence of edible coating and storage duration on post-harvest performance of plum [27].

Table 2: Weight loss (%), Decay percentage (%), Taste and color of banana fruit as affected by edible oil coating and storage life.

Treatment	Attributes			
Storage time	**Weight loss (%)**	**Decay percentage (%)**	**Taste**	**Colour**
0	0	0	6	4
3	2.52	0	6.33	6.16
6	5.02	0	7.16	7.16
9	5.51	3.47	7.66	7.5
12	9.3	11.10	7.67	7.66
LSD ($p \leq 5\%$)	0.08*	0.9*	0.18*	0.18*
coating oil				
Olive oil	5.05	5.41	6.6	6.2
Coconut oil	4.56	3.33	6.5	6
Butter oil	3.79	0	7.8	7.3

LSD (P≤ 5%)	0.07	0.7	0.15	0.15
Interaction storage time × coating oil	*	*	*	*

Note:*- LSD (Least Significant Difference)

CONCLUSION

It is concluded from the present experiment result that, the banana fruits coated with butter oil significantly affected by firmness, Titrate Acidity (TA), Ascorbic Acid (AA), weight loss, fruit decay, taste and color as compared to other edible oils, and control treatment. Olive oil can significantly affect Total Soluble Solid (TSS).

All the qualitative attributes of banana was significantly affected by storage duration. However firmness, TA, AA was significantly reduced while TSS, weight loss, fruit decay, was increased with increasing storage duration up to 12 days.

Furthermore, regarding interaction between treatment and storage duration (T × SD), Ascorbic Acid (AA), firmness, color, taste, weight loss of banana was significantly affected except Titratable Acidity (TA) and Total Soluble Solids (TSS).

CONFLICT OF INTERESTS

The authors have no conflicts of interest to declare in relation to this article.

ACKNOWLEDGMENTS

We are very thankful to the Faculty, postgraduates Department of Psychiatry SKIMS medical college, and Hospital Bemina for their valuable devotion and support.

FUNDING

The authors had no funders for authorship, research and publication of this article.

REFERENCES

1. Memon IN, Wagan H, Noonari S, Lakhio MH, Lanjar BA. Economic analysis of banana production under contract farming in Sindh Pakistan. Economic Analysis. 2016;21:14-21.
2. Bantayehu M. Fruit ripening and postharvest life of banana varieties at different temperatures and packaging. J Postharvest Technol. 2017;5(1):30-42.
3. FAO: Food and agriculture Organization.2018.
4. FAOSTAT. Banana facts and figures. 2017.
5. MNFSR. Ministry of National Food Security and Research. 2018.
6. D Antunes M, M Gago C, M Cavaco A, G Miguel M. Edible coatings enriched with essential oils and their compounds for fresh and fresh-cut fruit. Recent Pat food Nutr Agric. 2012;4(2):114-122.
7. Baloch MK, Bibi F, Jilani MS. Effect of coatings over the quality and shelf life of mango (*Mangifera indica L.*) fruit. J. Food Process Preserv. 2013;37(1):66-73.
8. Steel RGD, Torrie JH. Principles and procedures of statistics: A biometrical approach. (3rd edtn) McGraw Hill, New York. 1997.
9. Yaman Ö, Bayoındırlı L. Effects of an edible coating and cold storage on shelf-life and quality of cherries. LWT-Food Sci Technol. 2002;35(2):146-50.
10. Salunkhe DK, Bolin HR, Reddy NR. Storage, processing, and nutritional quality of fruits and vegetables. (Vol 1) Fresh fruits and vegetables. CRC press. 1991.
11. Şümnü G, Baymdirh L. Effects of sucrose polyester coating on fruit quality of apricots (*Prunus armenaica* (L)). J Sci Food Agric. 1995;67(4):537-540.
12. El-Anany AM, Hassan GF, Ali FR. Effects of edible coatings on the shelf-life and quality of Anna apple (*Malus domestica Borkh*) during cold storage. J Food Technol. 2009;7(1):5-11.
13. Khan MN, Nawaz MA, Ahmad W, Afzal M, Malik AU, Saleem BA. Evaluation of some exotic cultivars of sweet orange in Punjab, Pakistan. Int J Agric Biol. 2010;12:729-733.
14. Bindu MS, Jatinder M, Amandeep K. Effect of fruit ripening agents on composition and storage quality of muskmelon. Int J Curr Microbiol App Sci. 2017;6(9):2012-2018.
15. Rogez H, Pompeu DR, Akwie SN, Larondelle Y. Sigmoidal kinetics of anthocyanin accumulation during fruit ripening: a comparison between açai fruits (Euterpe oleracea) and other anthocyanin-rich fruits. J Food Compos Anal. 2011;24(6):796-800.
16. Park HJ. Development of advanced edible coatings for fruits. Trends F Sci Technol. 1999;10(8):254-260.
17. Shah ST, Basit A, Ullah I, Sajid M, Ahmad I, Ahmad I, et al. Influence of edible coatings and storage duration on post-harvest performance of plum. Pure Appl Biol. 2020;10(1):81-96.
18. Labuza TP. Moisture sorption: Practical aspects of isotherm measurement and use. American Association of Cereal Chemists, St. Paul, Minn. 2000.
19. Lim-Byung, S, S Choi, C Lee, Y Kim, B Moon. Effect of pro wax coating and keeping quality in Tsugaru apple during room and low temperature storage. J Hort Sci. 1998;40(1):96-101.
20. Grierson D. Senescence in fruits. Hort Sci. 1998;22:859-862.
21. Banerjee S, Basu PS. Hormonal regulation of flowering and fruit development: Effect of gibberellic acid and ethrel on fruit setting and development of *Momordica charantia L.* Biol Plant. 1992;34(1-2): 63-70.
22. El-Kereamy A, Chervin C, Roustan JP, Cheynier V, Souquet JM, Moutounet M, et al. Exogenous ethylene stimulates the long-term expression of genes related to anthocyanin biosynthesis in grape berries. Physiol Plant. 2003;119(2):175-182.
23. Goldstein JL, Swain T. Changes in tannins in ripening fruits. Phytochemistry. 1963;2(4):371-83.
24. Jackson RS. Wine science: Principles and applications, Academic Press. 2008.
25. Bouzayen M, Latché A, Nath P, Pech JC. Mechanism of fruit ripening. Plant developmental biology-biotechnological perspectives. 2009;1:319-339.
26. Helrich K. AOAC. Association of official and analytical chemist. 2012.
27. Seymour GB, Taylor JE, Tucker GA. Biochemistry of fruit ripening. Springer Science and Business Media. 2012.