Effect of edible gum Arabic coating on the shelf life and quality of mangoes (*Mangifera indica*) during storage

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Abstract This study evaluated the effect of treatment with gum Arabic edible coatings on shelf life and quality parameters of mangoes during 20 days at room temperature. Apple variety of mangoes of uniform size were obtained from small holder farms in Makueni County, Kenya and dipped in various concentrations of gum Arabic solutions [0, 10, 15 and 20% (w/v)] for 1 h, ensuring the coating solution uniformly covered the surface. Control fruits were dipped in distilled water only. The fruits were then air-dried on trays, packed in cardboard boxes and stored at room temperature (23 ± 2 °C) and normal relative humidity (45–60%). Changes in weight loss, ascorbic acid content, β -carotene, total soluble solids (TSS), titratable acidity (TA) and pH were determined using standard methods. Gum Arabic coatings (all levels) significantly ($p < 0.05$) reduced weight loss, delayed increase in TSS and development of β -carotene, while retaining ascorbic acid in the mangoes during storage compared to the controls. Gum Arabic treatments resulted into higher TA that corresponded with low pH in the mangoes compared to the control. Ripening was slower with gum Arabic treatments and a shelf life of 15 days was obtained for gum Arabic-treated mangoes compared to less than 10 days for the control. Gum Arabic coatings demonstrated gas and water vapour barrier properties, hence extending the shelf life of mangoes while maintaining quality. Gum Arabic treatment can therefore serve as an alternative preservation method

for mangoes at farm and transit levels without affecting quality parameters; giving farmers more revenue and reducing post-harvest losses.

Keywords Gum Arabic · Mangoes · Post-harvest losses · Edible coatings

Introduction

The mango (*Mangifera indica*), among the tropical fruits, has great market potential in the fresh form due to its sensorial characteristics and difficulty for immediate consumption. Fresh mangoes are highly appreciated for their flavour, taste, pleasant aroma and nutritional value (Shahnawz et al. 2012). The relatively short ripening period and reduced post-harvest life are however, the limiting factors influencing the economic value and utilization of mangoes in the tropics (Narayana et al. 1996). Mangoes are climacteric fruits; they cannot be preserved for long periods after harvesting at room temperature as they ripen within 2–10 days after harvest (Amin et al. 2008). During ripening, a series of metabolic activities occur resulting to chemical changes, increased respiration, change in structural polysaccharides leading to fruit softening, degradation of chlorophyll and carotenoids biosynthesis, starch hydrolysis to sugars hence ripening of fruits with softening of texture to acceptable quality (Herianus et al. 2003). Several treatments such as low temperature storage, drying and use of inorganic chemicals such as potassium metabisulphite have been studied to maintain quality and extend the shelf life of the fresh fruit (Gathambiri et al. 2006). Such methods have resulted to chilling injuries on the mango fruits and loss of volatile nutrients especially during drying. The inorganic chemicals result to adverse

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health conditions to consumers due its residual effect. Additionally, such methods are expensive to run and the small holder farmer may find challenges in adopting them at farm and market levels (Gathambiri et al. 2006).

The high perishability of intact and minimally processed fruits makes it necessary to develop methods aimed at preserving them for a longer duration during storage. Application of edible coatings has been identified. Edible coatings are formed when a layer of an edible material is applied on the surface of an intact or minimally processed fruit, forming a protective barrier (Guilbert 1986). This preserves the quality of such fruits by forming a film that acts as a partial barrier to gases like oxygen (O₂) and carbon dioxide (CO₂), water vapour and aroma compounds from escaping, creating a modified atmosphere around the fruit, decreasing the respiration rate and water loss and preserving texture and flavour (Baldwin 1994). Coatings are also used as carriers of additives such as antimicrobials and antioxidants (Olivas and Barbosa-Cánovas 2005).

Use of edible coatings like *Gum Arabic* that has been embraced in the preservation of tomatoes and cucumbers in Malaysia and Saudi Arabia respectively, has not been attempted in mango preservation. *Gum Arabic* is a dried, gummy exudate obtained from the stems and branches of *Acacia* species and it is the least viscous and most soluble hydrocolloids (Ali et al. 2010). Its extensive use in the industrial sector is because of its emulsification, film forming and encapsulation properties (Motlagh et al. 2006). It consists of a complex mixture of macromolecules of different sizes and composition; characterized by a high proportion of carbohydrates (~ 97%), predominantly composed of D-galactose and L-arabinose units, and, a low proportion of proteins (< 3%) (Islam et al. 1997). Some physico-chemical properties such as moisture, total ash content, volatile matter and internal energy are used as international Gum Arabic quality parameter; and this may vary depending on the origin and age of trees, exudation time, the storage type and climate. The solubility of Gum Arabic's carbohydrate hydrophilic and hydrophobic proteins is facilitated by moisture content. The total ash content determines the critical levels of foreign matter, insoluble matter in acid, calcium, potassium and magnesium (Mocak et al. 1998). Gum Arabic has been found to delay the ripening process, by slowing down the rate of respiration and ethylene production during storage (Baldwin et al. 1999).

The need for high quality products and the demand for minimal food processing and storage technologies has emphasized the concept of using edible coatings to extend the shelf life of fresh and minimally processed produce and protect them from harmful environmental effects. The application of the coating can be realized by dipping or spraying methods followed by film formation process like

removing the solvent (normally water), coagulation of proteins, solidification of gel structures or chemical reactions. Apple fruits coated with Gum Arabic resulted in a significant delay in the change in weight loss, titratable acidity, firmness, total soluble solids, decay and colour during cold storage when compared to the uncoated control (El-Anany et al. 2009). Its use has been incorporated in the wine gums as it produces a clarity that is higher than can be obtained by other hydrocolloids. It prevents sucrose from crystallizing. It provides a controlled flavour release and slows down melting in the mouth making the wine gum long lasting (Vivas et al. 2001).

The aim of this study was to assess the effect of gum Arabic edible coatings on the shelf life and quality attributes of fresh mangoes, pretreated with gum Arabic at different concentrations during storage at room temperature for 20 days. Weight loss, ascorbic acid content, β-carotene, total soluble solids (TSS), titratable acidity (TA) and pH of fruits were evaluated and are herein reported.

Materials and methods

Collection of mangoes

Apple variety of the mango fruits, of uniform size and free from visual symptoms at the mature green stage were obtained from smallholder farms in Makueni County, Kenya. The fruits were handpicked directly from the trees and de-sapped by placing them on mango leaves spread on the ground, with the part where the pedicel abscission zone is broken, facing down. They were allowed to drain the sap for 1 h after which they were kept in cool boxes then transported to the laboratory at Egerton University. They were temporarily stored at 4 °C then analyses were done on them the day after.

Formulation of gum Arabic solutions and application of the coating treatments

Finely ground gum Arabic powder from *Acacia Senegal* var. *kerensis* collected from Isiolo County, Kenya, was made into solutions at concentrations of 0, 10 and 15 and 20% (w/v) in distilled water with low heat (40 °C) for 15 min. The solutions were then left to cool to 20 °C. One hundred and twenty (120) mango fruits were randomly allocated to the four different treatments and each treatment was replicated three times (10 fruits/replicate). Each replicate group of the fruits was dipped in the respective concentrations of gum Arabic solution for 1 h until the coating solution uniformly covered the surface. The control fruits (30) were dipped in distilled water only. The fruits were then air-dried on trays, packed in cardboard boxes and

stored in a clean room under the normal room conditions of temperature (23 ± 2 °C) and relative humidity (45–60%).

Determination of weight change

Three fruits from each replicate were marked and individually weighed before storage commenced. Those fruits were subsequently weighed at each sampling interval date to track their weight changes for the entire experiment, until the mangoes got spoilt. Weight measurements were taken and their averages determined in order to compute the overall weight changes. Percentage weight change/loss was calculated using the following equation:

$$\% W_l = \left[\frac{(W_i - W_f)}{W_i} \right] \times 100\%$$

where W_l was the weight loss (%), W_i (g) and W_f (g) were the initial and final weights respectively.

Physico-chemical analysis

Preparation of crude extract

Three pieces of mangoes from each replicate subjected to the various gum Arabic treatments were randomly picked, peeled and blended into homogeneous solutions using an electric blender. The blended solutions were then analyzed for physico-chemical parameters including β -carotene, ascorbic acid, total soluble solids, titratable acidity and pH changes, as affected by the various treatments. Initial determinations were done on day zero (0) and thereafter at five (5) days intervals until the mangoes got spoilt.

Analysis of β -carotene

Two millilitres of the various sample solutions prepared, were measured using a 10 ml measuring cylinder and transferred to a mortar. Extraction of the colour was done by adding small portions of acetone and crushing the solution with a pestle until the residue was colourless. The extracts were combined into a 50 ml volumetric flask by draining through a funnel staffed with cotton wool. Twenty-five (25) millilitres of the extract was taken into a round bottom flask, which was then evaporated to dryness in a water bath at about 60 °C. To the evaporated sample, 1 ml of petroleum ether was added to dissolve the β -carotene. This was then eluted in a column chromatography (Rangana 1979).

Column preparation

Twenty grams of silica gel was weighed and activated by dissolving it in 1 ml of absolute ethanol. A slurry was

made with petroleum ether to have a column of 10–15 cm. At the top of the column, 1 g of anhydrous sodium sulphate was packed. Up to 50 mls of the sample was allowed to drain through the column. The elute was received in a 25 ml volumetric flask until the beta-carotene in the column was not seen. It was then shaken well, covered with an aluminum foil and stored in a dark place. Absorbance was then read at 450 nm. Readings were taken two more times on all the samples. The beta-carotene content was then calculated using the following formula (Rangana 1979):

$$\text{Concentration} = \frac{0.4}{0.12} \left(\text{Absorbance} * \frac{\text{Final volume}}{\text{Weight of sample}} \right) * \text{Dilution Factor}$$

Analysis of ascorbic acid

Fifty (50) millilitres of the sample solution was pipetted into 250 ml volumetric flask. Two (2) grams of solid potassium iodide was added. Ten (10) millilitres of both 0.5 M H_2SO_4 and 0.01 M potassium iodate solutions were then added into the flask simultaneously. The solution was then titrated immediately with 0.07 M sodium thiosulphate until it lost almost its entire colour. Two millilitres of starch indicator was then added and the titration process completed (Dioha et al. 2011). The procedure was replicated twice for all the samples. The titre values were obtained and their means calculated to get the ascorbic acid values.

Analysis of the total soluble solids (°Brix)

This was determined by use of a digital bench refractometer (range 0–32%). Homogeneous sample solutions prepared by blending the flesh of three mango samples subjected to the various concentrations of gum Arabic. A drop of the specific solution was placed on the prism-plate of the refractometer (Mazumdar and Majumder 2003). The reading obtained after adjusting the refractometer to the mark, was directly recorded as total soluble solids (°Brix) (Majidi et al. 2011). This was done on three replicated samples solutions and the refractometer was then calibrated afresh using distilled water prior to use for the next sample.

Determination of titratable acidity

Ten (10) millilitres of the various prepared mango sample solutions were transferred into a 250 mls conical flask by a pipette. An equal amount of distilled water was added into the flask. Phenolphthalein indicator (3–4 drops) was then added and the solution stirred. The contents were rapidly

titrated with 0.1 N NaOH solution and end point determined when there was a definite colour change (Majidi et al. 2011). The final burette reading was then noted and the calculation of titratable acidity done using the formula (Rangana 1979);

$$\% \text{ acid} = \frac{\text{mls NaOH used} \times \text{Milliequivalent factor}(0.064) \times 100}{\text{grams of sample}}$$

Determination of pH

The pH of the sample solutions were measured using an electric pH meter. Twenty (20) millilitres of freshly prepared sample, was placed in a beaker. The electrode end of the pH meter was used to agitate the solution until a stable reading was obtained. This was done on the three replicated samples of the same solutions respectively. Between readings the electrode was rinsed with distilled water to eliminate cross-contamination.

Statistical analysis

The data obtained from the experiments above were put to statistical analysis using statistical package SAS 9.3. The results were expressed as mean $\pm$ standard deviation. Means were analyzed for significant difference by analysis of variance (ANOVA) and the means were separated using Tukey's HSD ($p < 0.05$) test.

Results

Effect of gum Arabic surface coating and storage period on weight loss of mangoes

Gum Arabic coating treatments and storage period significantly ($p < 0.05$) affected weight loss of the mango fruits (Fig. 1). Weight loss increased significantly with the progression of storage period and reached the maximum on the 10th day for the control and the 15th day for the treatments, after which the mangoes were spoilt, respectively. All the coating treatments exhibited less fruit loss than the control fruits, however; there were no significant ($p \geq 0.05$) effects on the weight loss of the coated mangoes with increasing levels of gum Arabic concentration (Fig. 1).

Total soluble solids, titratable acidity and pH

TSS of mangoes was significantly ($p < 0.05$) affected by gum Arabic coating treatments, storage period, and their interactions. The control mangoes showed significant

Fig. 1 Effect of different coating treatments on the weight loss of mango during storage at room temperature

($p < 0.05$) increase in TSS that peaked on day 5 at 18.00%; however, gum Arabic coating treatments significantly ($p < 0.05$) delayed increase in TSS of mangoes during the storage period (Fig. 2). Among the gum Arabic treatments, 10% gum Arabic surface coating treatment showed insignificant change in TSS, while 15% and 20% treatments showed a drop in TSS in the first 10 days but increased thereafter till the 15th day when all the mangoes were spoilt (Fig. 2). Similarly, TA of mangoes was significantly ($p < 0.05$) affected by gum Arabic coating and the storage period. There was a decrease in TA with increased storage period for the control but for the treatments, TA increased for the first 5 days, after which it started decreasing with storage time except for 10% gum Arabic treatment, until the mangoes were spoilt (Fig. 3). In all treatments, TA was higher in the treatments compared to the control during storage (Fig. 3). With little TSS increments and low TA decreases in all the gum Arabic treatments, this implies that ripening was slower with the gum Arabic treatment.

Fig. 2 Effect of different coating treatments on the TSS of mangoes during cold storage at room temperature

Fig. 3 Effect of different gum Arabic coating treatments on titratable acidity of mangoes during storage at room temperature

β -Carotene and ascorbic acid contents and pH

The β -carotene concentration in the mangoes was significantly ($p < 0.05$) affected by gum Arabic coating treatments and the storage period (Fig. 4). The control mangoes and the treatments with 10% and 15% gum Arabic treatments showed little change in the first 5 days. However, thereafter, the β -carotene concentration in the control samples increased significantly ($p < 0.05$) and by day 10, the concentration was more than two-fold than that in the treatments. After day 10, control mangoes were spoilt but the β -carotene concentration in 10% and 15% gum Arabic treatments slightly dropped but the concentration at 20% gum Arabic treatment, the β -carotene concentration increased significantly ($p < 0.05$) and at day 15, it was marching the levels of the control mangoes at day 10.

The vitamin C concentration in the mangoes was significantly ($p < 0.05$) affected by gum Arabic coating treatments and the storage period (Fig. 5). The control mangoes and the treatments with 10% gum Arabic treatments exhibited little change in the first 5 days compared to 15% and 20% gum Arabic treatments. However, the 10% gum Arabic treatment had vitamin C concentration increasing to 0.94 and approached those in 15% and 20% treatments (0.86–1.02) after which their concentration

Fig. 4 Effect of different gum Arabic coating treatments on beta β -carotene content of mangoes during storage at room temperature

Fig. 5 Effect of different gum Arabic coating treatments on vitamin C content of mangoes during storage at room temperature

decreased steadily towards day 15 when the mangoes started getting spoilt. However, in most cases, the vitamin C concentrations were significantly ($p < 0.05$) higher in the treatments than in the control in most parts of the storage period.

The effect of gum Arabic treatments on pH was significant ($p < 0.05$) (Fig. 6). The control samples had pH increasing with respect to the storage period and the pH readings of the control were significantly higher than the treatment pH. The treatments had insignificant ($p > 0.05$) changes in the pH up to day 15th.

Discussion

There was a significant effect of the gum Arabic coating on weight loss and hence the shelf life of the treated mangoes was extended in contrast to the control. This may be as a result of gum Arabic forming a semipermeable barrier that blocks the stem end scar and the lenticels in the coated fruit against losing water vapours and gases consequently reducing transpiration (Ketsa and Prabhasavat 1992). This is because at harvesting, the pedicel detaches from the fruit, allowing the fruit sap to ooze out hence the mango losing water and reducing the fruit's mass. Baldwin et al. (1999) had also observed that carnauba wax coated mangoes had

Fig. 6 Effect of different gum Arabic coating treatments on pH of mangoes during storage at room temperature

less weight loss because of decreased moisture loss. The control fruits (0% gum Arabic coating) showed the highest percentage weight loss due to higher moisture loss and increased respiration through uninterrupted atmospheric column and lower relative humidity compared to the coated ones. The weight loss in control samples with time was similar to the results reported by Kramchote et al. (2008) and Mandal et al. (2018) for mangoes. Water content of fruits is a major factor in maintaining their quality. Therefore, low weight loss is important in maintaining the quality of fruits over a longer duration. This delayed senescence helps to extend the shelf life of fruits as demonstrated here that with gum Arabic coatings, the fruits could be stored for 15 days compared to the control mangoes that spoilt within 10 days. The effect of concentration of gum Arabic on weight loss was not clear, indicating that the lowest concentration used was effective in reducing the respiration rate.

The TSS of the control mangoes increased with the storage duration of the mangoes compared to the treatments that had TSS barely changing with duration. The TSS increment for the control was steep in the first 5 days after which it showed a drop afterwards. The sharp increase in TSS of the control mangoes happened possibly due to loss of water from the fruits and the ripening condition that results in the breakdown of complex carbohydrates into simple sugars hence increased TSS (Jain and Mukherjee 2011), while for the treatments, the gum Arabic film formed on the surface of mangoes slows ethylene synthesis thus delaying ripening and ultimately TSS accumulation (Fan et al. 1999). TSS accumulation has been associated with ripening and the highest levels (18.00%) recorded here were similar to 18.65% that were reported by for the same variety of mangoes (Islam et al. 2013). After the starch had been completely hydrolysed, there was no further increase in sugar occurring in the control samples. Moreover, the sugars were primary substrates for respiration, along with other organic acids hence the reduced TSS after the 5th day (Wills et al. 1980).

There was a fluctuation of the pH values of the surface coated and the control fruits during the storage period. The pH for the control samples increased steadily and this corresponded to reduced titratable acidity over the storage period. Organic acids such as citric and malic acids are primary substrates for respiration, hence, a decrease of acidity is expected in highly respiring fruits as seen in the control samples (El-Anany et al. 2009). On the other hand, for the treatments, the pH increment was little that also corresponded with slight changes in titratable acidity. Gum coating modified the atmosphere around the fruit by forming a semi-permeable film that prevented the migration of moisture and/or gases across the coat. This prevented the development of the acids more effectively

resulting to mangoes with lower pH values (higher titratable acidity) unlike the control samples (Yaman and Bayoindirli 2002).

As observed, the ascorbic acid increased initially then decreased afterwards. The mangoes used were mature green hence unripe and had the lowest ascorbic acid. The increase in ascorbic acid up to day 5 indicated the ripening process and after they fully ripened, ascorbic acid concentration decreased; a show of senescence towards day 10 for the control and day 15 for the treatments (Sammi and Masud 2007). These results were in agreement with the results obtained by Muhammad et al. (2014), who showed that the concentration of ascorbic acid is highest in the half ripe mango, followed by ripe mangoes then unripe mangoes have the least ascorbic acid concentration. The treatments caused ascorbic acid retention in mangoes during storage, which is in agreement with the results reported by Baldwin (1994). The retention of ascorbic acid by the treatments could be attributed to the retardation of oxidation process and due to the slow rate of conversion of L-ascorbic acid by ascorbic acid oxidase (Jain and Mukherjee 2011). This shows that gum Arabic treatment is appropriate for ascorbic acid retention during mango storage.

The change in β -carotene concentration in the control mangoes for the first 5 days was minimal but the concentration increased significantly thereafter due to fruit ripening that is accompanied by colour change and β -carotene synthesis. On the other hand, treatment with gum Arabic inhibited β -carotene synthesis in the fruits that retained the green colour, similar to results reported by Fonseca et al. (2004). For the sample with 20% gum Arabic treatment, the increased β -carotene could be attributed to decaying that led to β -carotene synthesis similar to ripening.

Conclusion

The results of the present study showed that gum Arabic coating could extend the shelf life of mangoes for up to 15 days and might be an effective farm based post-harvest treatment to extend shelf life while maintaining the physico-chemical qualities of mangoes during storage at room temperature.

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References

- Ali A, Maqbool M, Ramachandran S, Alderson PG (2010) Gum Arabic as a novel edible coating for enhancing shelf-life and improving postharvest quality of tomato (*Solanum lycopersicum* L.) fruit. *Postharvest Biol Technol* 58(1):42–47
- Amin M, Malik AU, Mazhar MS, Din IU, Khalid MS, Ahmad S (2008) Mango fruit de-sapping in relation to time of harvesting. *Pak J Bot* 40(4):1587–1593
- Baldwin EA (1994) Edible coatings for fresh fruits and vegetables: past, present, and future. In: Krochta JM, Baldwin EA, Nisperos-Carriedo MO (eds) *Edible coating and films to improve food quality*. Technomic Publishing Co., Lancaster, pp 25–64
- Baldwin EA, Burns JK, Kazokas W, Brecht JK, Haigenmaier RD, Bender RJ, Pesis E (1999) Effect of two edible coatings with different permeability characteristics on mango (*Mangifera indica* L.) ripening during storage. *Postharvest Biol Technol* 17:215–226
- Dioha I, Olugbemi O, Onuegbu T, Shahru Z (2011) Determination of ascorbic acid content of some tropical fruits by iodometric titration. *Int J Biol Chem Sci* 5(5):2180–2184
- El-Anany AM, Hassan GFA, Rehab Ali FM (2009) Effects of edible coatings on the shelf-life and quality of Anna apple (*Malus domestica* Borkh) during cold storage. *J Food Technol* 7:5–11
- Fan X, Blankenship SM, Mattheis JP (1999) 1-Methylcyclopropene inhibits apple ripening. *J Am Soc Hortic Sci* 124(6):690–695
- Fonseca MJO, Salomao LCC, Cecon PR, Puschmann R (2004) Fungicides and wax in postharvest preservation of mango ‘Haden’. *Acta Hort* 645:557–563
- Gathambiri CW, Karanja CN, Kiiru SN (2006) Effects of drying on the quality of mango slices. In: *Proceedings of tenth Kenya Agricultural Research Institute Biennial Conference*. Nairobi, Kenya
- Guilbert S (1986) Technology and application of edible protective films. In: Mathlouthi M (ed) *Food packaging and preservation*. Elsevier Applied Science, New York, pp 371–394
- Herianus JD, Singh LZ, Tan SC (2003) Aroma volatiles production during fruit ripening of Kensington Pride mango. *Post Harvest Biol Technol* 27:323–336
- Islam AM, Phillips GO, Sljivo A, Snowden MJ, Williams PA (1997) A review of recent developments on the regulatory, structural and functional aspects of gum arabic. *Food Hydrocoll* 11:493–505
- Islam MK, Khan MZH, Sarkar MAR, Absar N, Sarkar SK (2013) Changes in acidity, TSS, and sugar content at different storage periods of the postharvest mango (*Mangifera indica* L.) influenced by Bavistin DF. *Int J Food Sci* 2013, Article ID 939385. <https://doi.org/10.1155/2013/939385>
- Jain SK, Mukherjee S (2011) Enhancing keeping quality of fruits in mango cv. Langra. *Ind J Hortic* 68:142–144
- Ketsa S, Prabhasavat T (1992) Effect of skin coating on shelf life and quality of ‘Nang Klanwan’ mangoes. *Acta Hort* 321:764–770
- Kramchote S, Jirapong C, Wongs-Aree C (2008) Effects of 1-MCP and controlled atmosphere storage on fruit quality and volatile emission of ‘Nam Dok Mai’ mango. *Acta Hort* 804:485–492
- Majidi H, Minaei S, Almasi M, Mostofi Y (2011) Total soluble solids, titratable acidity and ripening index of tomato in various storage conditions. *Aust J Basic Appl Sci* 5(12):1723–1726
- Mandal D, Sailo L, Hazarika TK, Shukla AC (2018) Effect of edible coating on shelf life and quality of local mango cv. Rangkuai of Mizoram. *Res Crops* 19(3):419–424. <https://doi.org/10.31830/2348-7542.2018.0001.10>
- Mazumdar BC, Majumder K (2003) *Methods on physicochemical analysis of fruits*. Daya Publishing House, New Delhi
- Mocak J, Jurasek P, Phillips GO, Varga S, Casadei E, Chikamai BN (1998) The classification of natural gums. X. Chemometric characterization of exudate gums that conform to the revised specification of the gum arabic for food use, and the identification of adulterants. *Food Hydrocoll* 12(2):141–150
- Motlagh S, Ravines P, Karamallah KA, Ma Q (2006) The analysis of Acacia gums using electrophoresis. *Food Hydrocoll* 20:848–854
- Muhammad I, Ashiru S, Ibrahim DI, Kanoma AI, Sani I, Garba S (2014) Effect of ripening stage on vitamin C content in selected fruits. *Int J Agric Forest Fish* 2(3):60–65
- Narayana CK, Pal RK, Roy SK (1996) Effect of pre-storage treatments and temperature regimes on shelf life and respiratory behaviour of ripe Baneshan Mango. *J Food Sci Technol Mysore* 33:79–82
- Olivas GI, Barbosa-Cánovas GV (2005) Edible coatings for fresh-cut fruits. *Crit Rev Food Sci Nutr* 45:657–670
- Rangana S (1979) *Manual analysis of fruits and vegetables product*. Tata McGraw- Hill Co., Ltd., New Delhi
- Sammi S, Masud T (2007) Effect of different packaging systems on storage life and quality of tomato (*Lycopersicon esculentum* var. Rio Grande) during different ripening stages. *Int J Food Saf* 9:37–44
- Shahnawz M, Sheikh SA, Khaskheli SG (2012) Effect of storage on the physicochemical characteristics of the mango (*Mangifera indica* L.) variety. Langra. *Afr J Biotechnol* 11(41):9825–9828. <https://doi.org/10.5897/ajb11.3487>
- Vivas N, Vivas de Gaulejac N, Nonier MF, Nedjma M (2001) Effect of gum arabic on wine astringency and colloidal stability. *Progres Agricole et Viticole (France)* 118(8):175–176
- Wills RBH, Bambridge P, Scott KJ (1980) Use of flesh firmness and other objective tests to determine consumer acceptability of delicious apples. *Aus J Exp Agric* 20(103):252–256
- Yaman O, Bayındırlı L (2002) Effects of an edible coating and cold storage on shelf-life and quality of cherries. *LWT Food Sci Technol* 35(2):146–150

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