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# Effects of different plant leaf extracts on postharvest life and quality of mango (*Mangifera indica* L.)

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***Abstract* —** *An experiment was carried out to investigate the efficacy of plant leaf extracts on elongation of shelf life and maintenance of quality of harvested mangoes. Freshly harvested mature green mangoes cv. 'Calcuttia maldah' of uniform size and weight were dipped in 50% concentration of different plant leaf extracts and stored in ambient condition (32±2ºC and 65±5 % RH). The treatments were leaf extracts from five different plants viz. neem (Azadirachta indica), chinaberry (Melia azadirach), lantana (Lantana camara), ashok (Polyalthea longifolia) and cinnamomum (Cinnamomum zeylanicum) while control was the other treatment. In addition, carbendazim (fungicide) was also kept as a benchmark treatment. Each treatment composed of 5 mangoes and replicated thrice. For each replication destructive sample was also kept. The treatment with neem leaf extract gave the most promising result as there was minimum physiological weight loss, maximum ascorbic acid content, maximum acidity and minimum pH. Similarly, shelf life, total soluble solids, freshness and firmness were highest in neem leaf extract treated fruits next to the carbendazim treated fruits. Control was the most ineffective of all the treatment regarding all the parameters.*

***Keywords*— mango, post-harvest, plant leaf extracts.**

## I. INTRODUCTION

Mango (*Mangifera indica* L.), popularly known as "The king of the fruits", is one of the most popular fruit grown and consumed extensively throughout the tropical and sub-tropical region of the world. With a total production of 23.87 million, mango ranks third among the tropical fruits grown throughout the world (FAO, 2006). Owing to its unique fragrance, delicious taste and high nutritive value (Pal, 1998), mango has very high global demands. Mango contains significant amount of carbohydrates, provitamin A, vitamin C and soluble sugar (Samad et al., 1975). Being a climacteric fruit, it is generally harvested at mature green stage and ripens during post-harvest handling operations like transportation, storage, etc. Mango is a high moisture and high nutrient reserve containing commodity and as a result it is highly perishable in nature and susceptible to several post-harvest diseases (Haggag, 2010; Dodd et al., 1997). According to Islam et al. (2016), the most important problems regarding fruits production in tropical and sub-tropical regions of the world are postharvest losses and deterioration of nutritional quality of fruits. In developed countries the post-harvest losses in fresh fruit is estimated to be about 5-25% while that in developing countries it is about 20-50% (Khader, 1985 as cited in Islam et al., 2016). During post-harvest operations like natural ripening, physical handling and storage, approximately 30-50% fruits go wasted (Lashley, 1983). This high wastage of fruits is due to highly perishable nature and climacteric pattern of respiration (Islam et al., 2013). According to Gupta and Jain (2014), mango suffers 20-30% losses because of shorter storage life and faster ripening process. In addition to natural deterioration various post-harvest disease infections also play a major role in post-harvest losses of fruits. Among various diseases anthracnose, stem end rot and alternariose are the major ones that infect mango fruits (Haggag, 2010). These diseases cause rapid degradation and faster decay of fruits decreasing the quality and postharvest life of fruits. Enhancing the post-harvest life of mango fruits without losing its quality is a major challenge as it is a highly perishable commodity prone to several disease infestations.

Many post-harvest treatment methods and technologies like cold (refrigeration) storage, CA storage, MAP, treatment with ethylene inhibitors like 1-MCP, PGR treatment, wax treatment, etc. have been developed over the years for lengthening shelf life and maintaining post-harvest qualities of fruits (Pandey et al., 2017). But the accessibility and affordability of poor farmers to these advanced technologies is a matter of concern in most developing and under-

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developed countries. Most of the mango growers in those countries suffer heavy post-harvest losses of fruits as a result of natural deterioration and severity of diseases. Post-harvest diseases cause serious loss of both quality and quantity of fruits every year. Over the years, various fungicides like mancozeb, benomyl, carbendazim, thiabendazol, etc. have gained popularity among growers to control the post-harvest diseases of mango (Lee et al., 2009)and to enhance the storage life of fruits (Gupta and Jain, 2014). However, the use of these pesticides poses serious health hazards and leads to environmental contamination (Okinbo and Osuinde, 2003). In addition, due to their frequent application, there is a possibility of development of resistance in pathogen populations (Kumar et al., 2007). With growing health consciousness among people and increasing consumer demand for pesticide residue free agricultural commodities (Cutler and Cutler, 1999; Serrano et al., 2005) it is therefore important to find better alternatives that are cost effective, non-toxic and eco-friendly with low residual action to prevent disease infections and maintain post-harvest qualities of mango fruits. The necessity of developing eco-friendly post-harvest treatment methods as alternative to hazardous chemicals has become scientists' priority worldwide over the years (Phongpaichit et al., 2001).

According to Macias et al. (1997), natural plant extracts from higher plants that are non-hazardous to both human health and environment are better alternatives to chemicals for controlling post-harvest diseases of mango. In recent years numerous studies have been made on the use of natural plant extracts in controlling post-harvest diseases and there have been several reported cases of botanical extracts having antifungal activities (Das et al., 2010). Botanical extracts have attracted scientists' attention and gained popularity for their antibacterial and antifungal activity (Lee et al. 2007; Santas et al. 2010). The botanical extracts can provide an excellent opportunity to avoid or replace or reduce the use of harmful chemicals in post-harvest treatment of fruits for controlling various diseases as these extracts have been found to possess several antimicrobial properties. Moreover, plant extracts have the ability to decompose rapidly and do not cause any negative hazards to the environment unlike chemical pesticides (Fokialakis et al., 2006). Botanical extracts from different plants have been reported to have anti-fungal, anti- bacterial and other anti-microbial properties. So, the present study was carried out to evaluate the effectiveness of various plant leaf extracts for elongation of shelf life and maintenance of quality of harvested mangoes at ambient storage condition.

## II. MATERIALS AND METHODS

### 2.1. Experimental location:

The experiment was conducted in the laboratory of Department of Horticulture, Agriculture and Forestry University, Rampur, Chitwan, Nepal in July, 2017.

### 2.2. Specimen collection:

The fresh and healthy leaves of neem (*Azadirachta indica)*, chinaberry *(Melia azadirach),* ashok *(Polyalthea longifolia),* cinnamomum *(Cinnamomum zeylanicum*) and lantana *(Lantana camara*) were collected from the Agriculture and Forestry University periphery. The collected leaves were washed first with tap water and finally with distilled water and shade dried at room temperature for 24 hours. Carbendazim was bought from the nearby market.

### 2.3. Preparation of botanical extract:

The botanical extract treatment solutions were prepared on percentage weight basis according to the method described by Gahukar (1996). Dried leaves were chopped and grinded in a laboratory mortar to fine powder. The extracts were prepared by adding 100 ml of distilled water to 100 g of leaf powder separately and kept overnight. This resulted in 100% concentration of every plant extracts (1:1 w/v). Finally the aqueous treatment solutions of different leaf extracts were prepared by diluting the extracts to 50% using distilled water. Carbendazim treatment solution was prepared by mixing carbendazim 0.1% in hot water at 55 ºC and fruits were dipped for 10-15 minutes.

### 2.4. Collection and preparation of fruit samples:

Freshly harvested mature green stage mango cv. 'Calcuttia Maldah' of uniform size and maturity, good quality and free from any injury or disease were bought from the mango orchard of the University. The fruits were cleaned properly with distilled water to remove all the foreign matters like dust, dirt, mud, filth, etc. Fruits were then grouped in to similar size after washing with distilled water and used for the experiment. The cleaned fruits were dipped in 50% concentration of the prepared leaf extracts for 10-15 minutes and stored at ambient room condition (32±2ºC and 65±5 % RH).

### 2.5. Experimental design and treatments preparation:

The experiment was conducted in Completely Randomized Design (CRD) with seven treatments and three replications. Destructive sample was kept for each replication for carrying out physico-chemical analysis. The seven treatments were; T1: Chinaberry leaf extract, T2: Neem leaf extract, T3: Lantana leaf extract, T4: Ashok leaf extract, T5: Cinnamomum leaf extract, T6: Benchmark treatment with Carbendazim and T0: Control. Each treatment was composed of 5 mangoes.

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## III. OBSERVATIONS

Observations were made on the following parameters:

### 3.1. Physiological weight loss (%)

It was determined with the help of electronic digital balance.

$$\text{Weight loss (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

### 3.2. Firmness (lbs/cm$^2$)

Firmness of fruits was measured using handheld penetrometer after peeling thin layer of skin.

### 3.3. Total Soluble Solids ($^0$ Brix)

The total soluble solids ($^0$ Brix) was recorded by using hand held refractometer.

### 3.4. Titrable Acidity

Titrable acidity was determined by the titration of diluted fruit juice with few (2-3) drops of phenolphthalein against base (0.1N NaOH) solution.

$$\text{Total Titrable Acidity (\%)} = \frac{N_B \times V_B \times \text{Milliequivalent wt. of predominant acid} \times 100 \times df}{\text{Volume of sample}}$$

Where, $N_B$ = Normality of base (NaOH)

$V_B$ = Volume of the base

df = Dilution factor

### 3.5. pH

It was measured using automatic digital pH meter.

### 3.6. Vitamin C (Ascorbic acid)

Vitamin C content of fruit juice was determined by volumetric method following the procedure given by Sadasivam and Manickam (1996).

Calculation of the vitamin C content was done by using the following formula.

$$\text{Amount of ascorbic acid (mg/100g sample)} = \frac{0.5\text{mg}}{V_1} \times \frac{V_2}{5\text{ml}} \times \frac{100}{\text{Wt. of sample}} \times 100$$

### 3.7. Shelf life (Days)

Shelf-life of fruits was measured by counting the number of days from start of storage until when more than 50% of samples per replicate have been deteriorated .

### 3.8. Freshness and market acceptability

Evaluation of freshness and market acceptability was done by a panel of five people based on the color and appearance of fruits. Values of freshness were given in scale of 1-5 (5 = Fresh having good market acceptability, 2.5 = critical value for market acceptability and 1 = poor in freshness having no market acceptability).

## IV. STATISTICAL ANALYSIS

The collected data on various parameters were statistically analyzed using R-STAT statistical package program to find out the variation resulting from experimental treatments. Mean comparisons were made using Least Significant Difference (LSD) test at 5% probability level.

## V. RESULTS AND DISCUSSIONS

### 5.1. Physiological weight loss

A significant difference was recorded among treatments at various days of storage with respect to the physiological loss in weight. With increasing period of storage the physiological loss in weight also increased in all the treatments. Throughout the storage, the physiological weight loss was found to be lowest (13.07%) in fruits treated with 50% neem leaf extract as compared to other treatments (Table 1). It might be because of the ability of neem leaf extract to retard the moisture loss and to delay the senescence process as reported by Gakhukar (1996). Other probable reason for this might be the ability of neem leaves to restrict the growth of micro-organisms responsible for rotting as explained by Singh et al., (2000); Chauhan et al., (2008) and Bajwa and Ahmad (2012). The reduced weight loss might also be due to the formation of thin layer of oil on surface of fruits that reduced the evapotranspiration and respiration rate in the treated fruits (Singh et al., 2000). Samanta and Prasad (1996) have also reported the positive effects of leaf extracts on minimizing the water vapor losses from fruits.

Alongside neem, lantana leaf extract gave the lowest physiological weight loss in 5$^{th}$, 7$^{th}$ and 9$^{th}$ day. Except at 3$^{rd}$ day, there was no significant difference between neem leaf and lantana leaf extracts regarding physiological weight loss. Among the different botanical extracts treatments, polyalthea and cinnamomum leaf extract were the least effective. The maximum physiological weight loss was observed in untreated fruits (12.05%) on day 5. Neem leaf extract was more efficient than carbendazim in reducing the physiological weight loss i.e. by approximately 4 %.

*Table.1: Effect of plant extracts on physiological weight loss (%) of mango during different days until the end of shelf life on ambient room storage (32±2ºC and 65±5 % RH)*

| Treatments | Day 3 | Day 5 | Day 7 | Day 9 |
|---|---|---|---|---|
| **Control** | $6.06^{a}$±0.35 | $12.05^{a}$±0.27 | Discarded | |
| **Chinaberry leaf extract** | $2.72^{c}$±0.34 | $8.23^{c}$±0.43 | $11.34^{c}$±0.8 | $15.68^{bc}$±1.88 |
| **Neem leaf extract** | $1.93^{d}$±0.26 | $7.50^{c}$±0.16 | $9.99^{c}$±0.34 | $13.07^{c}$±0.53 |
| **Lantana leaf extract** | $2.53^{cd}$±0.04 | $7.85^{c}$±0.31 | $10.42^{c}$±0.48 | $13.15^{c}$±0.13 |
| **Polyalthea leaf extract** | $3.73^{b}$±0.37 | $10.92^{ab}$±0.34 | $16.03^{b}$±0.82 | $19.84^{a}$±0 |
| **Cinnamomum leaf extract** | $3.89^{b}$±0.17 | $11.56^{a}$±0.65 | $19.60^{a}$±0.89 | $19.29^{a}$±0 |
| **Carbendazim** | $4.41^{b}$±0.21 | $9.85^{b}$±0.44 | $14.14^{b}$±0.5 | $17.64^{ab}$±0.31 |
| **P-Value** | 0.00000011*** | 0.000000833*** | 0.000000736*** | 0.00685** |
| **LSD** | 0.705 | 1.114 | 1.912 | 3.286 |
| **CV (%)** | 11.15 | 6.55 | 7.91 | 7.71 |
| **Grand mean** | 3.61 | 9.70 | 13.586 | 16.395 |

Significance codes: 0.001 '***' 0.01 '**' 0.05'*' NS= non-significant. Values are means of three replications. Within a column, values having the same letter(s) do not differ significantly as per DMRT at 5% level.

**5.2. Firmness**

Alongside physiological weight loss, firmness is very important parameter regarding postharvest storage and its value is very effective for evaluating the fruit maturity (Olmo et al., 2000). The effects of different plant extracts on the firmness of mango fruits are given in Table 2. There was a significant difference in the firmness of fruits due to the dipping of the fruits in aqueous extracts of selected plant species. Carbendazim treated fruits showed the maximum retention of firmness (0.96 lbs/cm$^2$) until the final days of storage followed by neem leaf and lantana leaf extract treated fruits. At the third day of storage, control and chinaberry leaf extract treatments gave the lowest firmness value and in contrast, carbendazim treatment gave the highest firmness followed by neem leaf extract. Surprisingly, polyalthea, cinnamomum and chinaberry leaf extract treated fruits all showed similar firmness value as that of untreated fruits until fifth day of storage. Carbendazim treatment had the highest firmness in all days of storage. Except Carbendazim all other treatments were similar in seventh days of storage and while in ninth day of storage, neem leaf extract and lantana leaf extract had better firmness than other remaining treatments. In case of neem leaf extract treated fruits better firmness observed might be due to the effect of azadirachtin on pectin molecules (Sandeep et al., 2010). The experiment showed that the effects of neem and lantana leaf extracts on maintaining firmness of fruits were comparable to the effects of carbendazim treatment although carbendazim gave the highest firmness value. The retardation of degradation of insoluble protopectins to the more soluble pectic acid and pectin by different plant extracts might be the possible reason for better retention of firmness of treated fruits than untreated ones (Abbasi et al., 2009). Tehrani et al. (2011) also reported that the textural changes during ripening is related the loss of pectin substances from cell wall by various degrading enzymes. Labavitch and Ahmad (1978) suggested that the gradual conversion of carbohydrate in to sugar along with change in cell wall polysaccharides and uronic acid might be the reason for decrease in firmness of fruits.

*Table.2: Effect of plant extracts on firmness (lbs/cm$^2$) of mango during different days until the end of shelf life on ambient room storage (32±2ºC and 65±5 % RH)*

| Treatments | Initial | Day 3 | Day 5 | Day 7 | Day 9 |
|---|---|---|---|---|---|
| **Control** | | $8.5^{e}$±0.066 | $4.3^{c}$±0.066 | Discarded | |
| **Chinaberry leaf** | | $8.5^{e}$±0.066 | $4.3^{c}$±0.066 | $2.03^{b}$±0.1 | $0.3^{b}$±0.1 |

| | | | | | |
|---|---|---|---|---|---|
| **extract** | | | | | |
| **Neem leaf extract** | | $9.6^{b}$±0.066 | $5^{b}$±0.13 | $2.43^{b}$±0.1 | $0.76^{ab}$±0.1 |
| **Lantana leaf extract** | 13 | $9.36^{bc}$±0.1 | $4.8^{b}$±0.13 | $2.16^{b}$±0.1 | $0.7^{ab}$±0.1 |
| **Polyalthea leaf extract** | | $8.96^{d}$±0.1 | $4.03^{c}$±0.1 | $2.16^{b}$±0.1 | $0.4^{b}$±0 |
| **Cinnamomum leaf extract** | | $9.13^{cd}$±0.13 | $4.4^{c}$±0.13 | $2.16^{b}$±0.1 | $0.4^{b}$±0 |
| **Carbendazim** | | $12.4^{a}$±0.3 | $7.96^{a}$±0.23 | $3.4^{a}$±0.3 | $0.96^{a}$±0.13 |
| **P-Value** | | 0.0000000000424*** | 0.0000000000138*** | 0.000106*** | 0.0387* |
| **LSD** | | 0.380 | 0.354 | 0.415 | 0.459 |
| **CV (%)** | | 2.28 | 4.07 | 9.74 | 25.49 |
| **Grand mean** | | 9.49 | 4.97 | 2.39 | 0.586 |

Significance codes: 0.001 '***' 0.01 '**' 0.05'*' NS= non-significant. Values are means of three replications. Within a column, values having the same letter(s) do not differ significantly as per DMRT at 5% level.

**5.3. Total Soluble Solids (TSS)**

Statistically a highly significant variation was observed in TSS content of fruits among various treatments. TSS of treatments control, neem leaf extract and carbendazim increased throughout the storage period. TSS of other remaining treatments increased until the 7th day and then decreased (Table 3). Similar results were observed by Shinde et al., (2009). The initial increase in TSS might be due to the accumulation of sugar as a result of hydrolysis of insoluble polysaccharides (starch) into simple sugars, while the later decrease might be due to the consumption of sugar for respiration during storage (Kumar et al., 1994). TSS of carbendazim treated fruits were highest followed by neem leaf extract treated fruits at the end of storage period. There was a slow increase in TSS of neem leaf extract treated fruits in comparison to all other treatments. This might be due to the action of neem ingredients that have antifungal properties and also the thin film of neem oil on surface of fruits reduced the evapotranspiration and respiration rate and showed minimum decay thus preventing the rapid rise of TSS (Singh et al., 2000). Chauhan and Joshi (1990) also reported that botanical extracts performed better in retaining the total soluble solids in Ratna cv. of mango.

*Table.3: Effect of plant extracts on TSS ($^{0}$Brix) of mango during different days until the end of shelf life on ambient room storage (32±2$^{o}$C and 65±5 % RH)*

| **Treatments** | **Initial** | **Day 3** | **Day 5** | **Day 7** | **Day 9** |
|---|---|---|---|---|---|
| **Control** | | $11.13^{b}$±0.067 | $14.8^{a}$±0.267 | Discarded | |
| **Chinaberry leaf extract** | | $11^{b}$±0.133 | $13.4^{b}$±0.133 | $15.23^{b}$±0.233 | $14.4^{cd}$±0.2 |
| **Neem leaf extract** | | $10^{c}$±0.133 | $12.43^{c}$±0.1 | $14.4^{c}$±0.133 | $15.06^{b}$±0.067 |
| **Lantana leaf extract** | 5 | $10^{c}$±0.133 | $12.73^{c}$±0.067 | $15.03^{b}$±0.1 | $14.8^{bc}$±0 |
| **Polyalthea leaf extract** | | $10.33^{c}$±0.067 | $14.4^{a}$±0.133 | $16.03^{a}$±0.1 | $14^{d}$±0 |
| **Cinnamomum leaf extract** | | $10.3^{c}$±0.067 | $14.46^{a}$±0.267 | $16^{a}$±0.133 | $14^{d}$±0 |
| **Carbendazim** | | $12.06^{a}$±0.2 | $14.73^{a}$±0.067 | $15.13^{b}$±0.067 | $16.26^{a}$±0.067 |
| **P-Value** | | 0.0000000185*** | 0.0000000271*** | 0.00000634*** | 0.0000328*** |
| **LSD** | | 0.33 | 0.45 | 0.386 | 0.403 |
| **CV (%)** | | 1.77 | 1.85 | 1.419 | 0.99 |

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| | | | | | |
|---|---|---|---|---|---|
| **Grand mean** | | 10.68 | 13.85 | 15.30 | 14.75 |

Significance codes: 0.001 '***' 0.01 '**' 0.05'*' NS= non-significant. Values are means of three replications. Within a column, values having the same letter(s) do not differ significantly as per DMRT at 5% level.

**5.4. Titrable Acidity (TA)**

The variation of TA of fruits was found to be significant until the 7th of storage. TA on the 9th day of storage was found to be non-significant. The TA of fruit was highest at zero days of storage and then a decreasing trend of titrable acid content was observed with the advancement of storage period (Table 4). The decrease in acidity during the storage period might be due to the conversion of citric acid into sugars and their further utilization in various metabolic processes of fruit (Doreyapp and Huddar, 2001; Mizrach et al., 1997; Rathore et al., 2007; Srinivasa et al., 2002). Neem leaf extract treated fruits had the highest TA throughout the storage period. The decrease in TA of neem leaf extract treated fruits was found to be slowest followed by carbendazim treated fruits due to their effects on the utilization of organic acids in respiration which delayed the physiological ageing and restricted the starch degradation. Similar observations were also confirmed by the findings of Singh et al. (2000). Chinaberry treatment gave the lowest TA value at the end of storage period.

*Table.4: Effect of plant extracts on TA of mango during different days until the end of shelf life on ambient room storage (32±2ºC and 65±5 % RH)*

| Treatments | Initial | Day 3 | Day 5 | Day 7 | Day 9 |
|---|---|---|---|---|---|
| **Control** | 2.12 | $1.45^{b}$±0.09 | $0.85^{b}$±0.046 | Discarded | |
| **Chinaberry leaf extract** | | $1.31^{b}$±0.006 | $0.84^{b}$±0.073 | $0.43^{c}$±0.048 | $0.28^{a}$±0.035 |
| **Neem leaf extract** | | $1.75^{a}$±0.026 | $1.09^{a}$±0.08 | $0.76^{a}$±0.053 | $0.44^{a}$±0.046 |
| **Lantana leaf extract** | | $1.64^{a}$±0.06 | $0.97^{ab}$±0.048 | $0.53^{bc}$±0.031 | $0.37^{a}$±0.05 |
| **Polyalthea leaf extract** | | $1.33^{b}$±0.06 | $0.86^{b}$±0.07 | $0.50^{c}$±0.051 | $0.30^{a}$±0 |
| **Cinnamomum leaf extract** | | $1.64^{a}$±0.06 | $0.84^{b}$±0.086 | $0.53^{bc}$±0.053 | $0.30^{a}$±0 |
| **Carbendazim** | | $1.73^{a}$±0.03 | $1.07^{a}$±0.081 | $0.67^{ab}$±0.064 | $0.42^{a}$±0.032 |
| **P-Value** | | 0.000105*** | 0.0436* | 0.00277** | $0.15^{NS}$ |
| **LSD** | | 0.164 | 0.197 | 0.141 | 0.167 |
| **CV (%)** | | 6.05 | 12.04 | 13.82 | 16.47 |
| **Grand mean** | | 1.55 | 0.931 | 0.57 | 0.351 |

Significance codes: 0.001 '***' 0.01 '**' 0.05'*' NS= non-significant. Values are means of three replications. Within a column, values having the same letter(s) do not differ significantly as per DMRT at 5% level.

**5.5. pH**

The analysis of variance between the treatments exhibited significant variation regarding the pH value of mango fruits at different days of storage except on 9th day (Table 5). The pH value was lowest at zero days of storage and it gradually increased with the advancement of storage period. This increasing trend of pH value during storage period was also observed by Shahjahan et al. (1994). This phenomenon of increasing trend of pH during storage might be possible due to the oxidation of acids resulting in higher pH (Md. Khairul Islam, M. Z. H. Khan, M. A. R. Sarkar, Nurul Absar, and S. K. Sarkar, 2013). Control treatment had the highest pH until 5th day while Cinnamomum treated fruits had the highest pH after day 5. The increase in pH value was found to be slower in carbendazim treatment on 3rd and 5th days of storage, while on 7th day both neem leaf extract and carbendazim treatment had the same pH value. But on 9th day of storage, neem leaf extract treated fruits had the lowest pH value followed by carbendazim treatment exhibiting that neem leaf extract helps in slowing down ripening process better than carbendazim. Cinnamomum treatment had the highest pH value on the 9th day of storage.

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*Table.5: Effect of plant extracts on pH of mango during different days until the end of shelf life on ambient room storage (32±2ºC and 65±5 % RH)*

| Treatments | Initial | Day 3 | Day 5 | Day 7 | Day 9 |
|---|---|---|---|---|---|
| **Control** | 2.2 | $3.26^{a}$±0.1 | $3.90^{a}$±0.067 | Discarded | |
| **Chinaberry leaf extract** | | $3.26^{a}$±0.067 | $3.56^{bc}$±0.1 | $3.90^{a}$±0.067 | $4.45^{a}$±0.05 |
| **Neem leaf extract** | | $3.03^{bc}$±0.1 | $3.40^{cd}$±0.133 | $3.56^{b}$±0.1 | $4.30^{a}$±0.133 |
| **Lantana leaf extract** | | $3.10^{abc}$±0.067 | $3.40^{cd}$±0.133 | $3.73^{ab}$±0.133 | $4.50^{a}$±0.1 |
| **Polyalthea leaf extract** | | $3.23^{ab}$±0.033 | $3.53^{c}$±0.033 | $3.90^{a}$±0.067 | $4.40^{a}$±0 |
| **Cinnamomum leaf extract** | | $3.20^{ab}$±0.067 | $3.80^{ab}$±0.067 | $3.93^{a}$±0.033 | $4.60^{a}$±0 |
| **Carbendazim** | | $2.93^{c}$±0.033 | $3.23^{d}$±0.033 | $3.56^{b}$±0.033 | $4.36^{a}$±0.033 |
| **P-Value** | | 0.0149* | 0.000401*** | 0.00699** | $0.469^{NS}$ |
| **LSD** | | 0.194 | 0.238 | 0.221 | 0.369 |
| **CV (%)** | | 3.535 | 3.841 | 3.311 | 3.094 |
| **Grand mean** | | 3.144 | 3.545 | 3.763 | 4.435 |

Significance codes: 0.001 '***' 0.01 '**' 0.05'*' NS= non-significant. Values are means of three replications. Within a column, values having the same letter(s) do not differ significantly as per DMRT at 5% level.

**5.6. Vitamin C (Ascorbic acid)**

All the treatments had significant effects on the vitamin C content of fruits at all days of storage. In all the treatments except control, ascorbic acid content first increased for first 7 days and then was found to decrease on 9$^{th}$ day of storage (Table 6). Vitamin C content increased until the storage period of untreated (control) fruits. This trend of first increase in vitamin C might be attributed to the reason that the fruits are still maturing. The decrease of vitamin C during storage might be due to the rapid conversion of l-ascorbic acid in to dehydro-ascorbic acid in presence of enzyme ascorbinase (Mapson 1970) which is further consumed during metabolic process of the fruits. Some investigators have found an increase in vitamin C content with maturation (Banerjee and Romasorama, 1938 as cited in Spencer et al., 1956) while others have noted a decrease (Hawaiian Agr. Expt. Sta. Report, 1943 as cited in Spencer et al., 1956).Vitamin C was observed lowest at zero days of storage for all the treatments except Cinnamomum treatment which had lowest vitamin C at 9$^{th}$ day of storage. Neem leaf extract treatment had maximum retention of ascorbic acid i.e. the highest vitamin C content among all at 7$^{th}$ and 9$^{th}$ day of storage. This might be due to the influence of neem leaf extracts in retarding ripening and oxidation processes as well as slowing down the respiration rate of fruits (Singh et al., 2000).

*Table.6: Effect of plant extracts on Vitamin C (mg/100g) of mango during different days until the end of shelf life on ambient room storage (32±2ºC and 65±5 % RH)*

| Treatments | Initial | Day 3 | Day 5 | Day 7 | Day 9 |
|---|---|---|---|---|---|
| **Control** | 9.8 | 9.90$^{e}$±0.067 | 10.93$^{f}$±0.1 | Discarded | |
| **Chinaberry leaf extract** | | 9.83$^{e}$±0.1 | 10.90$^{f}$±0.067 | 13$^{f}$±0.133 | 10.31$^{c}$±0.085 |
| **Neem leaf extract** | | 10.43$^{d}$±0.02 | 12.39$^{d}$±0.133 | 19.34$^{a}$±0.267 | 11.45$^{a}$±0.16 |
| **Lantana leaf extract** | | 10.93$^{c}$±0.033 | 12.67$^{c}$±0.05 | 17.10$^{c}$±0.067 | 10.51$^{c}$±0.05 |
| **Polyalthea leaf extract** | | 10.89$^{c}$±0.02 | 12.90$^{b}$±0.047 | 14$^{e}$±0.073 | 10.98$^{b}$±0 |
| **Cinnamomum leaf extract** | | 12.51$^{a}$±0.013 | 14.33$^{a}$±0.047 | 16.08$^{d}$±0.113 | 9.74$^{d}$±0 |
| **Carbendazim** | | 11.75$^{b}$±0.033 | 12.04$^{e}$±0.073 | 18.54$^{b}$±0.053 | 10.54$^{c}$±0.0267 |
| **P-Value** | | 0.00000000000000226*** | 0.0000000000000762*** | 0.00000000000056*** | 0.00047*** |
| **LSD** | | 0.135 | 0.213 | 0.379 | 0.410 |
| **CV (%)** | | 0.707 | 0.988 | 1.304 | 1.419 |
| **Grand mean** | | 10.89 | 12.30 | 16.34 | 10.588 |

Significance codes: 0.001 '***' 0.01 '**' 0.05'*' NS= non-significant. Values are means of three replications. Within a column, values having the same letter(s) do not differ significantly as per DMRT at 5% level.

**5.7. Shelf life**

The variation in shelf life of fruits due to different treatments was found to be highly significant. The longest shelf life (11 days) was recorded in carbendazim treated fruits with lowest disease infestations and the shortest (5 days) was recorded in untreated (control) fruits with highest disease infestations. Neem leaf extract treated fruits had shelf life of 9 days which was the longest among all other botanical extracts although other botanical extract treatments were not statistically different (Table 7). The disease infestation was also found to be lowest in neem leaf extract among botanical extract treatments. It might be due to the antifungal properties of neem preventing the microbial growth and its thin film reducing the evapotranspiration and respiration rate (Singh et al., 2000).

*Table.7: Effect of plant extracts on shelf life (days) of mango on ambient room storage (32±2ºC and 65±5 % RH)*

| Treatments | Shelf life |
|---|---|
| **Control** | 5$^{c}$±0 |
| **Chinaberry leaf extract** | 8.33$^{b}$±0.667 |
| **Neem leaf extract** | 9$^{b}$±0 |
| **Lantana leaf extract** | 8.33$^{b}$±0.667 |
| **Polyalthea leaf extract** | 7.66$^{b}$±0.667 |
| **Cinnamomum leaf extract** | 7.66$^{b}$±0.667 |
| **Carbendazim** | 11$^{a}$±0 |
| **P-Value** | 0.0000592*** |
| **LSD** | 1.528 |
| **CV (%)** | 10.71 |
| **Grand mean** | 8.14 |

Significance codes: 0.001 '***' 0.01 '**' 0.05'*' NS= non-significant. Values are means of three replications. Within a column, values having the same letter(s) do not differ significantly as per DMRT at 5% level.

**5.8. Freshness and market acceptability**

There was a significant difference in the freshness or marketability of fruits as a result of treatment of the fruits with different plant extracts (Table 8). Carbendazim treatment had the highest freshness value throughout the storage period except on day 3 and discarded only on 11$^{th}$ day while control had the lowest value of freshness and discarded on 5$^{th}$ day. Carbendazim, a fungicide prevented the fruits from fungal infection (anthracnose) so the fruits had greater freshness value. Neem leaf extract treatment was next best after carbendazim on 3$^{rd}$, 5$^{th}$ and 7$^{th}$ day in terms of freshness value. However both the neem leaf extract and carbendazim treatment were statistically similar. It might be due to the antifungal properties of neem preventing the microbial growth and its thin film reducing the evapotranspiration and respiration rate (Singh et al., 2000). Polyalthea and cinnamomum gave the poorest results among plant extract treatments.

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*Table.8: Effect of plant extracts on freshness of mango during different days until the end of shelf life on ambient room storage (32±2ºC and 65±5 % RH)*

| Treatments | Initial | Day 3 | Day 5 | Day 7 | Day 9 |
|---|---|---|---|---|---|
| **Control** | 5 | 4.31$^{c}$±0.1 | 2.21$^{c}$±0.13 | Discarded | |
| **Chinaberry leaf extract** | | 4.81$^{ab}$±0.05 | 4.11$^{b}$±0.067 | 2.96$^{ab}$±0.416 | 2.27$^{b}$±0.025 |
| **Neem leaf extract** | | 4.96$^{a}$±0.03 | 4.41$^{a}$±0.083 | 3.55$^{a}$±0.116 | 2.30$^{b}$±0.083 |
| **Lantana leaf extract** | | 4.90$^{ab}$±0.03 | 4.31$^{ab}$±0.1 | 3.06$^{ab}$±0.366 | 2.37$^{b}$±0.075 |
| **Polyalthea leaf extract** | | 4.80$^{ab}$±0.05 | 4.08$^{b}$±0.083 | 2.58$^{b}$±0.35 | 2.20$^{b}$±0 |
| **Cinnamomum leaf extract** | | 4.78$^{b}$±0.067 | 4.08$^{b}$±0.083 | 2.55$^{b}$±0.283 | 2.20$^{b}$±0 |
| **Carbendazim** | | 4.91$^{ab}$±0.0167 | 4.53$^{a}$±0.033 | 3.76$^{a}$±0.016 | 2.86$^{a}$±0.067 |
| **P-Value** | | 0.00000889*** | 0.000000000198*** | 0.0356* | 0.00385** |
| **LSD** | | 0.157 | 0.250 | 0.820 | 0.300 |
| **CV (%)** | | 1.880 | 3.607 | 14.968 | 4.569 |
| **Grand mean** | | 4.78 | 3.96 | 3.076 | 2.366 |

Significance codes: 0.001 '***' 0.01 '**' 0.05'*' NS= non-significant. Values are means of three replications. Within a column, values having the same letter(s) do not differ significantly as per DMRT at 5% level.

## VI. CONCLUSION

Different plant leaf extracts imposed to this investigation showed significant variation in terms of post-harvest qualities and shelf life of mango. The present study revealed that postharvest dipping of mango fruits on plant extracts can improve the post-harvest quality and extend the shelf life of fruits. All the leaf extracts treatment gave decent results as all of them gave superior performance than the control. There was minimum physiological weight loss, maximum ascorbic acid content, maximum acidity and minimum pH in neem leaf extract treatment. Similarly, shelf life, total soluble solids, freshness and firmness were highest in neem leaf extract treated fruits next to the carbendazim treated fruits. The performance of neem leaf extract was superior among other leaf extract treatments and was comparable with the bench mark (carbendazim) treatment; indicating that, the use of plant extracts can be a better alternative for maintaining quality and extending post-harvest life of mango in place of hazardous chemical pesticides.

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