Efficacy of Plant Extracts to Prolong Shelf Life: A Study on Neem and Turmeric in Preservation of Mango Fruits

ABSTRACT

Ethnobotanists, microbiologists, and natural-products chemists are actively exploring the Earth for phytochemicals and potential alternatives to synthetic fungicides for post-harvest management of fruits and vegetables. Although 25 to 50% of modern medicines are derived from plants, none are currently utilized as antimicrobials. Traditional growers have long relied on plants to prevent or treat infectious conditions, and Western medicine is now seeking to replicate their successes. Plants contain a diverse range of secondary metabolites, including tannins, terpenoids, alkaloids, and flavonoids, which have demonstrated antimicrobial properties in vitro. This study aimed to evaluate the efficacy of extracts from two plants neem and turmeric on extending the shelf life of mango fruits (cv. Gulabkhas) under two storage conditions: cool storage and ambient conditions. The fruits were treated with four concentrations of each plant extract (5%, 10%, 15%, and 20%) and placed in perforated linear low-density polyethylene bags. They were then stored under the specified conditions of cool storage and ambient storage. The combination of neem leaf extract treatment with cool storage yielded promising results. By the end of the storage study, the treatment of 20% neem leaf extract in cool storage completely inhibited pathogens, resulting in no spoilage. This combination also demonstrated minimal physiological weight loss (6.2%), low spoilage rates, and maximum ascorbic acid content (28.5 mg per 100 g of pulp). Additionally, it exhibited minimal acidity (0.12%), maximum total soluble solids (20.1ºB), and the highest levels of total sugars (12.50%), reducing sugars (3.5%), and non-reducing sugars (8.55%). The organoleptic score was also notably high at 7.3 out of 10. The inhibitory effect of neem leaf extract is attributed to the active principle azadirachtin. This study highlights the potential of neem leaf extract as an effective and natural alternative for extending the shelf life of mango fruits during storage. Therefore, the successful application of neem extract provides a promising avenue for future research and practical implementation in post-harvest technology.

Keywords, Mango storage, plant extracts, neem, casuarina, turmeric

1. INTRODUCTION

Mango referred to as the "King of Fruits," is cultivated in India across 1.23 million hectares, producing nearly 10.99 million tonnes annually [1]. This accounts for over 55% of the total mango production worldwide. Currently, Gulabkhas is the most commonly cultivated early mango variety in Southern and Eastern India, prized for its short stature, sweet taste, pinkish hue, and early ripening [2]. As a perishable fruit, mango have a very short shelf life and typically reach the peak of their respiration rate during the ripening process on the third or fourth day after harvesting at ambient temperatures [3, 4]. The shelf life of mango varies among different varieties and is influenced by storage conditions. At room temperature, it ranges from 4 to 8 days, while in cold storage at 13ºC, it can extend to 2 to 3 weeks [5, 6]. This limited shelf life poses significant challenges for the long-distance commercial transport of mango [7, 8]. Typically, the ripening process for mature green mango takes between 9 to 12 days after harvesting [9, 10]. The ripening of mango fruit encompasses a complex series of biochemical reactions. This process is characterized by heightened respiration rates and ethylene production, leading to changes in structural polysaccharides that cause softening [11, 12]. Additionally, chlorophyll degradation occurs alongside the biosynthesis of pigments from carotenoids. Concurrently, carbohydrates undergo transformation, with starch converting into sugars, and the production of organic acids, lipids, phenolics, and volatile compounds. Collectively, these changes contribute to the ripening of the fruit, resulting in a softer texture that meets quality standards [10, 13]. The sensitivity of fruit to decay, combined with its low temperature tolerance and general perishability due to rapid ripening and softening, restricts its storage, handling, and transportation capabilities [14]. Conversely, the use of modified atmosphere (MA) or controlled atmosphere (CA) storage is not always suitable for mango. While CA storage has been demonstrated to prolong the shelf life of mango, it can be prohibitively expensive. Although MA storage has been reported to delay mango ripening, it often leads to elevated carbon dioxide levels and undesirable off-flavors [15-17].

Fungal spoilage is the primary cause of post-harvest rot in fresh fruits and vegetables during storage and transportation [18, 19]. This has led to significant losses during the commercialization phase. In recent years, growers have increasingly adopted the use of various fungicides, growth regulators, and waxing materials to extend the shelf life of fruits. However, the growing resistance of certain post-harvest fungal pathogens to approved fungicides has become a major concern [20, 21], their residual toxicity, contribution to environmental pollution, and adverse effects on human health [22, 23]. There has been a growing effort to develop alternative control measures [16, 24, 25]. Plant extracts have recently gained popularity and scientific interest for their antibacterial and antifungal properties [26, 27]. Several plants found in India have been successfully utilized for therapeutic purposes. The antimicrobial activity of many of these plants against post-harvest pathogens has been demonstrated in citrus [28], mango [8], papaya [8] and yam [29]. Grainge et al., [30] documented and classified various plants from different families known for their growth-regulating and fungicidal properties. For instance, neem (*Azadirachta indica*) has shown remarkable effectiveness, with several commercial products already available in the market. Similarly, rhizome extracts of turmeric (*Curcuma longa*) and leaf extracts of casuarina (*Casuarina equisetifolia*) are well-known for their germicidal, insecticidal, and growth-regulating properties. Previous studies have evaluated the potential of plant extracts from neem, Karanj, custard apple leaves, and marigold flowers for extending the post-harvest shelf life of apple fruits (cv. 'Starking Delicious') [31] and mango varieties (cv. 'Langra' and 'Dasheri') [32]. Therefore, the objective of this study was to assess the effect of these plant extracts on the post-harvest shelf life and the physico-chemical changes in mango fruits (cv. 'Gulabkhas') during storage under ambient and low-temperature conditions.

2. MATERIALS AND METHODS

2.1 Preparation of Plant Extracts

Fresh leaves of Neem (*Azadirachta indica*) and Casuarina (*Casuarina equisetifolia*), as well as fresh rhizomes of Turmeric (*Curcuma longa*), were collected. After drying, the plant materials were ground using a mechanical grinder to obtain a fine powder. Subsequently, 200 g of this powder was soaked in 1,000 ml of sterile distilled water for 6 hours and then filtered through muslin cloth. The resulting filtrate served as a stock solution (100%), which was further diluted to prepare coating solutions of varying strengths.

2.2 Treatment and Storage Conditions for Mature Gulabkhas Mango

Fully matured and uniformly sized fruits of the mango variety Gulabkhas were selected for this study. The fruits were collected from the Fruit Research Station at Orissa University of Agriculture

Technology. In the laboratory, the fruits were sorted to ensure uniformity in size, shape, and maturity stage. After sorting, the fruits were thoroughly washed in running water to remove any dirt and dust, then air-dried. The fruits were randomly divided into ten lots, each receiving different plant extract treatments. The treatments included: distilled water (control, T1); neem leaf extracts at concentrations of 5% (T2), 10% (T3), 15% (T4), and 20% (T5); turmeric powder at 10% (T6) and 20% (T7); and casuarina leaf extracts at 10% (T8) and 20% (T9). Each treatment was supplemented with 2% guar gum as a sticking agent. The control fruits were treated with distilled water containing 2% guar gum. The fruits were immersed in their respective treatments for 30 minutes and then placed on newspaper sheets to dry in the shade for an additional 30 minutes. After treatment, the fruits from each lot were packed in polythene bags with a thickness of 200 gauge, featuring 5% perforated area. Each treatment was replicated, and the fruits were stored under two conditions: in a refrigerator at 7 ± 1 °C and 85% relative humidity, and under ambient conditions with an average temperature of 36 °C and 75.8% relative humidity

2.3 Assessment of Quality Attributes in Gulabkhas Mango During Storage

Observations on physiological loss in weight (PLW), spoilage, organoleptic score, total soluble solids (TSS), acidity, ascorbic acid content, total sugars, and reducing sugars were recorded at four-day intervals over a 12-day storage period. PLW was calculated by weighing the fruits on a physical balance, while spoilage was expressed as a percentage. Total soluble solids (TSS) were measured using a digital refractometer and reported in degrees Brix. The acidity and ascorbic acid content of the samples were determined using the titrimetric method outlined by [33], and the total and reducing sugar content was analyzed using colorimetric methods as described by [34]. Organoleptic evaluation was conducted by a panel of ten judges, who scored the samples on a scale of 1 to 10. The initial values recorded at the beginning of the experiment (day 0) were as follows: sensory score: 4.10; total soluble solids: 17.1%; acidity: 0.38%; ascorbic acid: 47.45 mg per 100 g of pulp; total sugars: 10.03%; and reducing sugars: 2.8%.

2.4 Statistical analysis

The experiment was conducted using a factorial completely randomized design (factorial CRD), consisting of 20 treatment combinations, each with three replicates. Each replicate included five uniformly sized fruits of mango cv. Gulabkhas. The data were analyzed using analysis of variance (ANOVA) with statistical software, and the critical difference (C.D. at P ≤ 0.05) was employed to compare the means [35]. Percentages were transformed into arcsine square root values to normalize the distribution prior to ANOVA; however, the results are presented as untransformed percentage data.

3. RESULTS AND DISCUSSION

3.1 Physiological loss in weight (PLW)

PLW was significantly lower in fruits treated with 20% neem leaf extract compared to the control and other treatments (Table 1).

Table 1. Effect of plant extracts and storage conditions on the percentage of physiological loss in *Mangifera indica* cv. Gulabkhas.

Treatments	Storage Periods (Days)					
	3		6		9	
	Cold Storage	Atm. Temp.	Cold Storage	Atm. Temp.	Cold Storage	Atm. Temp.
Control	4.0	8.3	6.3	20.8	9.1	32.6
Neem 5%	3.2	5.4	5.9	18.3	8.2	29.2
Neem 10%	2.8	5.2	5.7	18.1	8.3	28.5
Neem 15 %	1.6	4.7	5.4	16.3	6.5	25.1
Neem 20%	1.2	4.6	5.2	15.4	6.2	21.2
Turmeric 10%	3.8	6.7	6.3	19.9	8.8	29.5
Turmeric 20%	2.5	6.4	6.0	18.3	8.4	28.3
Casuarina 10%	2.2	5.8	5.8	18.0	7.2	27.7

Casuarina 20%	2.3	5.1	5.5	16.7	7.3	27.2
	S.E.(m)	C.D. at 5%	S.E.(m)	C.D. at 5%	S.E.(m)	C.D. at 5%
Treatments	0.021	0.053	0.012	0.042	0.031	0.891
Storage condition	0.003	0.022	0.002	0.032	0.021	0.062
Interaction	0.021	0.051	0.027	0.052	0.010	0.043

This effect may be attributed to the extract's ability to slow moisture loss and delay the senescence process, as noted by [36]. Additionally, the neem leaf extract's antimicrobial properties may inhibit the growth of microbes responsible for decay and high metabolic rates, further contributing to its effectiveness in reducing PLW [31, 32]. Among the different storage conditions, mango fruits stored under cool conditions exhibited the least PLW compared to those kept at ambient temperatures. The low temperature and high humidity associated with cool storage likely reduced PLW by minimizing moisture loss through decreased respiration rates and transpiration. These findings align with observations reported by Doreyappy and Huddar [37] for mature green Alphonso mango.

3.2 Spoilage

Spoilage was primarily caused by rotting due to pathogenic microorganisms. On the 9th day of storage, no spoilage was observed in fruits treated with 15% and 20% neem leaf extract when stored under cool conditions, while untreated fruits at ambient temperature exhibited spoilage rates of 38.6% and 35.1%, respectively (Table 2).

Table 2. Effect of plant extracts and storage conditions on the spoilage percentage of of *Mangifera indica* cv. Gulabkhas.

Treatments	Storage Periods (Days)					
	3		6		9	
	Cold Storage	Atm. Temp.	Cold Storage	Atm. Temp.	Cold Storage	Atm. Temp.
Control	-	-	23.6	42.2	28.2	60.5
Neem 5%	-	-	5.1	281	91	48.1
Neem 10%	-	-	5.0	28.5	8.3	45.2
Neem 15 %	-	-	0.0	20.0	0.0	38.6
Neem 20%	-	-	0.0	19.3	0.0	35.1
Turmeric 10%	-	-	12.2	37.7	17.1	50.2
Turmeric 20%	-	-	10.2	37.2	15.5	43.1
Casuarina 10%	-	-	8.7	31.4	13.2	38.6
Casuarina 20%	-	-	8.1	31.1	13.1	38.7
	S.E.(m)	C.D. at 5%	S.E.(m)	C.D. at 5%	S.E.(m)	C.D. at 5%
Treatments	-	-	2.570	6.765	2.123	6.210
Storage condition	-	-	1.118	3.021	1.061	3.280
Interaction	-	-	3.425	NS	3.125	9.122

The reduction in spoilage associated with neem leaf extract can be attributed to the presence of the active compound azadirachtin, which effectively inhibits the growth of pathogens responsible for rotting [36, 38]. Additionally, the cooler storage conditions resulted in less contamination and infection compared to ambient conditions [39]. It is evident that the inhibitory effect of neem leaf extract was more pronounced in cool storage compared to ambient temperatures. Similar findings have been reported by Baswa et al. [10].

3.3 Organoleptic score

Overall, the organoleptic score of the fruits initially increased before gradually declining, regardless of the treatment or storage condition. This pattern likely reflects the ripening process followed by senescence. However, within treatments, fruits treated with 20% neem leaf extract exhibited slower changes in organoleptic scores compared to the control group. These results are consistent with the findings of Bhardwaj et al. [15]. At the end of the storage period, the highest organoleptic score was recorded for fruits treated with 20% neem leaf extract, while the control group had the lowest mean score (Table 3).

Table 3. Influence of plant extracts and storage conditions on the organoleptic score (Rated out of 10) of *Mangifera indica* cv. Gulabkhas.

Treatments	Storage Periods (Days)					
	3		6		9	
	Cold Storage	Atm. Temp.	Cold Storage	Atm. Temp.	Cold Storage	Atm. Temp.
Control	5.5	7.0	7.7	3.2	4.2	1.1
Neem 5%	5.5	7.8	7.2	3.8	6.9	1.3
Neem 10%	5.3	7.5	7.1	3.7	6.7	1.5
Neem 15 %	5.2	7.1	7.2	3.5	6.5	0.7
Neem 20%	5.1	7.0	7.1	3.4	7.3	0.6
Turmeric 10%	5.8	7.9	7.3	3.7	7.1	3.1
Turmeric 20%	5.7	7.9	7.0	3.6	6.2	3.3
Casuarina 10%	5.6	7.6	6.9	3.5	5.6	2.6
Casuarina 20%	5.5	7.2	6.8	3.3	5.8	2.2
	S.E.(m)	C.D. at 5%	S.E.(m)	C.D. at 5%	S.E.(m)	C.D. at 5%
Treatments	0.011	0.021	0.011	0.012	0.010	0.031
Storage condition	0.002	0.011	0.002	0.25	0.001	0.012
Interaction	0.012	0.043	0.013	0.033	0.012	0.041

This decline in the control group can be attributed to rapid degradative changes in carbohydrates, acids, phenolic compounds, and spoilage, leading to a loss of color and flavor [40]. Additionally, the changes in overall organoleptic scores were slower in fruits stored in cool conditions compared to those stored at ambient temperature (Table 3). This difference may be due to the reduced rate of metabolic changes associated with ripening and senescence under the low-temperature conditions of cool storage.

3.4 Total soluble solids (TSS)

Initially, the TSS content in the fruits increased, likely due to the hydrolysis of insoluble polysaccharides into simpler sugars. However, this content gradually declined, possibly due to a reduction in carbohydrates and pectin, partial hydrolysis of proteins, and the decomposition of glycosides into subunits during respiration. At the conclusion of the storage study, the highest TSS content was observed in fruits treated with 20% neem leaf extract (Table 4).

Table 4. Effect of plant extracts and storage conditions on total soluble solids (°Brix) of *Mangifera indica* cv. Gulabkhas.

Treatments	Storage Periods (Days)					
	3		6		9	
	Cold Storage	Atm. Temp.	Cold Storage	Atm. Temp.	Cold Storage	Atm. Temp.
Control	18.1	19.1	21.1	19.1	19.1	15.1
Neem 5%	18.3	19.1	20.2	19.3	19.2	15.2

Neem 10%	18.2	19.2	20.1	19.6	19.1	15.2
Neem 15 %	18.7	19.6	20.7	19.8	19.2	16.2
Neem 20%	18.1	20.8	21.2	20.1	20.1	17.3
Turmeric 10%	18.2	18.1	19.1	18.7	18.1	15.1
Turmeric 20%	18.9	18.3	19.8	18.2	18.3	15.1
Casuarina 10%	18.2	18.3	20.2	18.2	19.2	16.5
Casuarina 20%	18.7	18.2	20.2	18.1	19.1	16.1
	S.E.(m)	C.D. at 5%	S.E.(m)	C.D. at 5%	S.E.(m)	C.D. at 5%
Treatments	0.011	0.032	0.011	0.021	0.011	0.031
Storage condition	0.001	0.011	0.020	0.010	0.001	0.011
Interaction	0.012	0.041	0.011	0.041	0.011	0.041

This increase may be attributed to a reduced respiration rate and delayed ripening associated with this treatment. In contrast, the control fruits exhibited the lowest TSS content, likely due to greater respiratory losses since there was no barrier to impede gas exchange within the fruit [32]. The increase in TSS was observed to be more rapid in fruits stored at room temperature compared to those stored in cooler conditions. This phenomenon can be attributed to the high temperatures and low relative humidity at room temperature, which facilitate the conversion of starch and other insoluble carbohydrates into soluble sugars. Consequently, the TSS and sugars were consumed during respiration, resulting in lower concentrations within the fruit tissues. In contrast, prolonged storage of mango fruits at low temperatures with high humidity in cool storage may hinder the ripening process, leading to reduced TSS values. These findings align with previous studies by Joshi and Roy [41] regarding room temperature storage, as well as Kapse et al. [42] and Krishnamurthy and Joshi [43] regarding cool storage conditions for mango fruits.

3.5 Total acids

The acidity of the fruit was highest at the start of the storage period and decreased over time. This decline may be attributed to the rapid utilization of acids in the fruit pulp during respiration and the degradation of citric acid, which likely contributes to the reduction in acidity as these acids are converted into sugars and subsequently utilized in the fruit's metabolic processes. Different treatments with plant extracts significantly affected the ripening processes, with fruits treated with neem leaf extract exhibiting a greater retention of acidity during storage (Table 5).

Table 5. Effect of plant extracts and storage conditions on acidity content (%) of *Mangifera indica* cv. Gulabkhas.

Treatments	**Storage Periods (Days)**					
	3		**6**		**9**	
	Cold Storage	Atm. Temp.	Cold Storage	Atm. Temp.	Cold Storage	Atm. Temp.
Control	0.21	0.21	0.21	0.14	0.18	0.03
Neem 5%	0.31	0.21	0.22	0.11	0.12	0.05
Neem 10%	0.31	0.21	0.21	0.13	0.12	0.03
Neem 15 %	0.30	0.21	0.20	0.12	0.17	0.03
Neem 20%	0.30	0.23	0.20	0.11	0.12	0.03
Turmeric 10%	0.31	0.28	0.21	0.11	0.18	0.02
Turmeric 20%	0.31	0.28	0.21	0.12	0.19	0.03
Casuarina 10%	0.32	0.28	0.21	0.12	0.20	0.01
Casuarina 20%	0.35	0.21	0.20	0.1	0.19	0.01

	S.E.(m)	C.D. at 5%	S.E.(m)	C.D. at 5%	S.E.(m)	C.D. at 5%
Treatments	0.001	0.003	0.001	0.003	0.001	0.002
Storage condition	0.001	0.002	0.001	0.003	0.000	0.001
Interaction	0.001	0.003	0.001	0.005	0.001	0.003

This effect may be due to the treatment's ability to delay physiological aging and alter metabolic processes, resulting in higher acidity retention. Similar findings have been reported by [14, 44, 45]. The rate of acidity reduction was observed to be more rapid in fruits stored at room temperature compared to those stored in cooler conditions. This difference may be attributed to the high temperatures and low humidity typical of ambient storage, which likely accelerate the degradation of organic acids into sugars and their utilization during respiration. In contrast, prolonged storage of mango fruits at low temperatures and high humidity in cool storage appears to inhibit the degradation of organic acids. Similar findings have been reported by [41, 46] regarding ambient storage conditions, as well as by Krishnamurthy and Joshi [43] in cooler storage. These results are also consistent with the observations made by Doreyappy and Huddar [37], Garcia et al. [47], and Srinivasa et al. [48].

3.6 Ascorbic acid

In general, there was a gradual decline in vitamin C content across all treatments during storage. The rate of decrease in vitamin C was significantly higher in untreated control fruits compared to those that were treated. This difference may be attributed to a rapid loss of vitamin C through oxidation, which is facilitated by the greater availability of oxygen. The reduction in ascorbic acid during storage could result from the swift conversion of L-ascorbic acid into dehydroascorbic acid in the presence of the enzyme ascorbinase [49]. The highest mean ascorbic acid retention was observed in fruits treated with 20% neem leaf extract, recording 36.27 mg of ascorbic acid per 100 g of pulp (Table 6).

Table 6. Effect of plant extracts and storage conditions on ascorbic acid content (mg/100 g of pulp) of *Mangifera indica* cv. Gulabkhas.

Treatments	**Storage Periods (Days)**					
	3		**6**		**9**	
	Cold Storage	Atm. Temp.	Cold Storage	Atm. Temp.	Cold Storage	Atm. Temp.
Control	41.3	40.2	36.6	25.1	26.2	15.2
Neem 5%	40.8	40.2	35.1	24.2	26.4	15.2
Neem 10%	41.4	41.4	36.1	25.2	27.6	16.2
Neem 15 %	42.3	41.1	37.4	26.5	27.7	17.4
Neem 20%	43.5	41.7	38.7	27.6	28.5	17.6
Turmeric 10%	40.3	40.2	34.2	23.3	25.5	14.6
Turmeric 20%	40.1	40.1	34.6	23.4	26.7	14.7
Casuarina 10%	41.1	41.0	35.9	24.5	26.3	15.3
Casuarina 20%	42.1	41.1	36.1	25.4	27.1	16.1
	S.E.(m)	C.D. at 5%	S.E.(m)	C.D. at 5%	S.E.(m)	C.D. at 5%
Treatments	0.015	0.041	0.011	0.045	0.024	0.065
Storage condition	0.001	0.012	0.006	0.026	0.015	0.023
Interaction	0.021	0.051	0.023	0.075	0.034	0.092

This retention may be due to the neem leaf extract's influence in reducing both respiration rates and oxidation processes in the fruits. The superior retention of ascorbic acid in cool storage compared to ambient temperature storage can be attributed to the lower temperatures and higher relative humidity conditions. This finding aligns with observations made by Keleny et al. [50] during the cool chamber storage of mango fruits.

3.7 Total and reducing sugars

Storage conditions significantly influenced the effectiveness of treatments on the total and reducing sugar content of mango fruits (Table 7 and Table 8).

Table 7. Effect of plant extracts and storage conditions on total sugar content (%) of *Mangifera indica* cv. Gulabkhas.

Treatments	**Storage Periods (Days)**					
	3		**6**		**9**	
	Cold Storage	Atm. Temp.	Cold Storage	Atm. Temp.	Cold Storage	Atm. Temp.
Control	11.0	12.0	12.1	10.6	12.2	5.5
Neem 5%	11.2	12.1	12.2	10.1	12.2	5.6
Neem 10%	11.1	12.6	12.2	10.3	12.3	5.4
Neem 15 %	11.1	12.7	13.3	10.2	12.3	5.4
Neem 20%	12.0	13.1	13.5	11.1	12.5	5.7
Turmeric 10%	11.2	12.3	12.0	10.1	12.1	5.4
Turmeric 20%	11.2	12.3	12.6	10.2	12.2	5.4
Casuarina 10%	11.4	12.5	12.4	10.2	12.4	5.5
Casuarina 20%	11.2	12.3	13.2	10.4	12.3	5.1
	S.E.(m)	C.D. at 5%	S.E.(m)	C.D. at 5%	S.E.(m)	C.D. at 5%
Treatments	0.005	0.022	0.008	0.001	0.010	0.020
Storage condition	0.001	0.012	0.001	0.010	0.004	0.011
Interaction	0.010	0.31	0.010	0.011	0.012	0.43

Table 8. Effect of plant extracts and storage conditions on reducing sugar content (%) of *Mangifera indica* cv. Gulabkhas.

Treatments	**Storage Periods (Days)**					
	3		**6**		**9**	
	Cold Storage	Atm. Temp.	Cold Storage	Atm. Temp.	Cold Storage	Atm. Temp.
Control	3.2	3.1	3.3	2.8	3.2	2.6
Neem 5%	3.1	3.1	3.4	3.1	3.1	2.7
Neem 10%	3.1	3.2	3.4	3.1	3.1	2.8
Neem 15 %	3.2	3.7	3.6	3.2	3.4	3.1
Neem 20%	3.4	4.0	3.8	3.4	3.5	3.1
Turmeric 10%	3.2	3.1	3.2	3.2	3.2	2.5
Turmeric 20%	3.1	3.1	3.4	3.3	3.2	2.7
Casuarina 10%	3.3	3.3	3.4	3.4	3.2	2.6
Casuarina 20%	3.2	3.2	3.6	3.1	3.0	2.7
	S.E.(m)	C.D. at 5%	S.E.(m)	C.D. at 5%	S.E.(m)	C.D. at 5%
Treatments	0.011	0.030	0.011	0.031	0.011	0.031
Storage condition	0.002	0.012	0.007	0.016	0.002	0.011
Interaction	0.013	0.300	0.018	0.043	0.013	0.042

On the third day of storage, mango stored at ambient temperature exhibited higher sugar levels compared to those stored in cooler conditions. This difference may be attributed to the high temperature and low relative humidity at room temperature, which facilitate the conversion of starch and other insoluble carbohydrates into soluble sugars. These sugars are subsequently utilized during respiration, leading to lower sugar content in the later stages of storage. In contrast, the low temperatures in cool storage reduce fruit metabolism, particularly respiratory activity, which delays the ripening process and extends fruit shelf life by up to two weeks [51]. These observations align with findings reported by Joshi and Roy (1985) for room temperature storage, as well as Kapse et al. [42] and Krishnamurthy and Joshi [43] in cool storage conditions for mango fruits. Fruits treated with neem leaf extract exhibited a slower increase in sugar content due to reduced metabolic rates and lower respiration rates compared to the control fruits.

4. CONCLUSION

In conclusion, this study underscores the effectiveness of neem and turmeric extracts as viable alternatives to synthetic fungicides for managing post-harvest mango fruit. The findings indicate that applying a 20% neem leaf extract during cool storage not only completely inhibits spoilage pathogens but also preserves fruit quality, as evidenced by minimal weight loss and elevated levels of ascorbic acid and sugars. These results highlight the significance of investigating plant-based solutions within agricultural practices, suggesting that integrating traditional knowledge with contemporary research can lead to sustainable and effective strategies for extending the shelf life of fruits and vegetables. The successful use of neem extract opens promising avenues for future research and practical applications in post-harvest technology.

INSTITUTIONAL REVIEW BOARD STATEMENT

Not applicable.

INFORMED CONSENT STATEMENT

Not applicable.

DATA AVAILABILITY STATEMENT

Data is available in the manuscript.

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