



RESEARCH ARTICLE

Evaluation of surface coating and shrink-wrap packaging on shelf life and quality of mango cultivar 'Neelum'

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ABSTRACT

Kerala, the Indian state has the distinction of producing the earliest mangoes in the country, in February and the season extends up to May, coinciding with South West monsoon. Mango cultivar 'Neelum', the last commercial variety to attain maturity in the State is hampered by the incidence of fruit fly and anthracnose disease. An attempt was made during 2019-20 to extend the availability of the fruits of this cultivar by giving a surface coating with 'Nipro Fresh' wax containing the fungicide, Carbendazim, followed by shrink-wrap packaging in trays made of areca nut leaf sheath, before sanitizing with chlorine (100 ppm) and alum solution (1%). Surface coating with 'Nipro Fresh', followed by shrink-wrap packaging of trays containing mangoes, and their subsequent storage in cool chamber at 12-13 °C and 85-90 % relative humidity, extended the shelf life by 54 days, compared to the uncoated and unwrapped samples which had a shelf life of 9 days under ambient conditions. Respiration rate, physiological loss in weight, total soluble solids and carotenoids showed a steady rise while titratable acidity, total phenols and ascorbic acid recorded a declining trend.

Introduction

Mango, the national fruit of India, ranks third in terms of area and production in the state of Kerala. It is cultivated in an area of 79496 hectares with a production of 420048 tonnes (1). The fruit is a good source of carotenoids, ascorbic acid, phenols and dietary fibre. Mango varieties grown in Kerala start attaining maturity as early as February, which is the earliest in the country and the season extends up to May in the State. The variety 'Neelum', regarded as one of the choicest varieties of India, is a late season variety in Kerala. It attains maturity in the second fortnight of May, the period when the South West monsoon sets in the State. This results in hampering the quality of the fruits due to severe incidence of fruit fly and anthracnose disease caused by *Colletotrichum gloeosporioides*, which occurs as a latent infection during storage. This is further compounded by market gluts and huge post harvest losses, which are recurring phenomena in the State. 'Neelum', being the last variety to attain maturity in Kerala, extension of shelf life and maintenance of quality are of utmost significance to make the fruits available in the markets of the State. Hence, the present investigation was carried out with the view of extending the shelf life of mango cv. 'Neelum' and also, to maintain its quality during post harvest handling.

Materials and Methods

Post harvest handling

Mango fruits grown in the orchard of the College of Agriculture, Vellanikkara, Kerala Agricultural University, were harvested 110 days after fruit set and were quickly transported in plastic crates to the laboratory under the Department of Post Harvest Technology, College of Agriculture. The pedicels were clipped to retain 1 cm length of the stalk. The fruits were immediately subjected to desapping (drainage of exuding sap from the clipped pedicel) by keeping the fruits on news paper for 10 min. This was followed by sorting, to remove the damaged and malformed fruits. The fruits were then sanitized by treatment with 100 ppm chlorine, followed by dipping in 1 % alum solution for 3 min. The sanitized fruits were then subjected to destaining (to avoid sap injury) by gently rubbing the surface of the fruits with foam dipped in dilute detergent solution. The destained fruits were then dipped in clean water to remove traces of detergent from the fruit surface. After destaining, the fruits were immersed in a wax solution, 'Nipro Fresh MTS40' @ 5 % (Nipro-Fresh is an organic formulation, eco-friendly, non-ammonia based wax coating for use on fruits and vegetables that are intended to be stored in cold storage or are transported over long distances

{Nipro Technologies LLC, Spokane, Washington} (Manufacturer and Supplier: Nipro Technologies Ltd, Panchkula, Haryana, India) in combination with the fungicide, Benfil (Carbendazim 50 WP) @ 0.1 % for 5 min. [Post harvest treatment of apples, banana, citrus, mangoes, pears etc. with Carbendazim has been approved by Australian Pesticides and Veterinary Medicines Authority (PO Box. E 240, Kingston Act, 2604, Australia). The ICAR- National Research Centre for Banana, Trichy has also approved the use of Carbendazim (Bavistin) for post harvest treatment in banana. However, the wax and fungicide can be removed before consumption by soaking the fruits in lukewarm water alone or water containing vinegar or baking soda for 5 min and finally washing the fruits in clean water. Though acute toxicity of fungicides to humans is generally considered to be low, but can be irritating to skin and eyes. Consumption of excess Carbendazim can cause throat irritation, sneezing and coughing]. The treated fruits were then air dried under fan to remove excess moisture from the surface. These fruits were subsequently precooled at 12-13 °C, for 8 hr. This was followed by over-wrapping of four fruits of about 200 gm each, loosely on a tray made of areca nut leaf sheath with polyolefin film of 25 µ thickness with an impulse sealer and then passing it through the tunnel of the shrink wrapping machine maintained at 120 °C for 10 seconds, resulting in a consumer pack in which four mangoes on areca nut leaf sheath tray, which was tightly wrapped with the polyolefin film. These consumer packs of mangoes were subsequently held under two storage conditions viz. Ambient temperature [30-32 °C (maximum) and 18-20 °C (minimum) with 85-90 % RH] and cool chamber (12-13 °C and 85-90 % RH) along with the unwrapped samples. The fruits without wax treatment and shrink wrapping, under ambient and cool chamber storage, formed the control samples. The experiment consisted of six treatments viz. T1- unwrapped fruits without waxing stored under ambient conditions, T2- unwrapped fruits without waxing stored in cool chamber, T3- waxed fruits stored under ambient conditions, T4- waxed fruits stored in cool chamber, T5- waxed fruits with shrink wrapping under ambient conditions and T6- waxed fruits with shrink wrapping stored in cool chamber.

Quality characteristics

Physiological loss in weight (PLW): PLW was calculated as cumulative per cent loss in weight from the initial fruit weight before storage and the loss in weight recorded on the day of observation during storage under ambient and cool chamber conditions.

Respiration rate

An oxygen/carbon dioxide analyser was used for determining the rate of respiration of the samples (Model- Dansensor, CheckPoint O₂/CO₂, Denmark). A digital display provided the level of carbon dioxide liberated by the samples. The results were expressed in percentage of CO₂ accumulated in the head space of the sample.

Shelf life

Mango, being a climacteric fruit, the day on which the fruits became unmarketable was determined by taking into consideration the respiratory peak of the

fruits in the various treatments and the subsequent reduction in firmness.

Firmness

The firmness of fruits during storage was determined by a digital fruit firmness tester (Vaiseshika, Model-6003E, India), after removing a slice of the rind of the fruit along with a thin portion of the pulp, followed by insertion of the plunger of the tester into the fruit. The values were expressed as force required (in kg) to complete penetration (1 cm).

Total Soluble Solids (TSS)

Estimation of TSS was done by a digital refractometer (Atago, Japan) and the results were expressed in per cent degree Brix.

Titrateable acidity

Titrateable acidity of the fruits was estimated by titrating a known weight of the sample against 0.1 N NaOH solution using phenolphthalein as an indicator. The acidity was calculated and expressed as percent citric acid (2).

Ascorbic acid

Ascorbic acid was determined by titrating known weight of sample with 2, 6-dichlorophenol indophenol dye, using metaphosphoric acid as stabilizing agent (2).

Total phenols

Estimation of total phenols was carried out with Folin-Ciocalteu reagent. Phenols react with phosphomolybdic acid in alkaline medium and produce a blue coloured complex (Molybdenum blue) (3). The optical density values were recorded at 650 nm (UV-Visible 1800 spectrophotometer, Shimadzu, Kyoto, Japan).

Total carotenoids

Determination of total carotenoids was done by extraction with acetone and petroleum ether (4). The optical density values were measured at 452 nm (UV-Visible 1800 spectrophotometer, Shimadzu, Kyoto, Japan).

Statistical analysis

The experiment was laid out in the Complete Randomized Design (CRD) and the data gathered was statistically analysed using WASP (Web Agriculture Statistical Package).

Results and Discussion

Surface coating and shrink-wrap packaging were effective in prolonging the shelf life of mango fruits of cv. 'Neelum' and also had considerable advantage on maintaining the quality attributes of the fruits.

Physiological loss in weight (PLW)

PLW showed an upward trend in all the treatments during storage (Fig. 1). Surface coating of fruits with Nipro Fresh resulted in significant reduction in weight loss under ambient and low temperature storage. PLW value was the lowest in the fruits subjected to wax coating followed by shrink-wrap packaging and subsequently held in cool chamber, throughout storage. Weight loss in fruit without surface coating and shrink wrapping, stored under ambient conditions was the highest (24.3 %), after 9

days of storage while it was only (11.2 %) in the fruits subjected to the combined treatment of wax coating and shrink-wrap packaging, followed by holding in cool chamber, after 54 days of storage. Surface coating and shrink-wrap packaging may have resulted in the passive modification of atmospheric gases surrounding the produce, leading to accumulation of higher levels of CO₂. This, along with low temperature storage might have reduced the metabolic activities of the fruits, leading to significant reduction in weight loss. These results are in

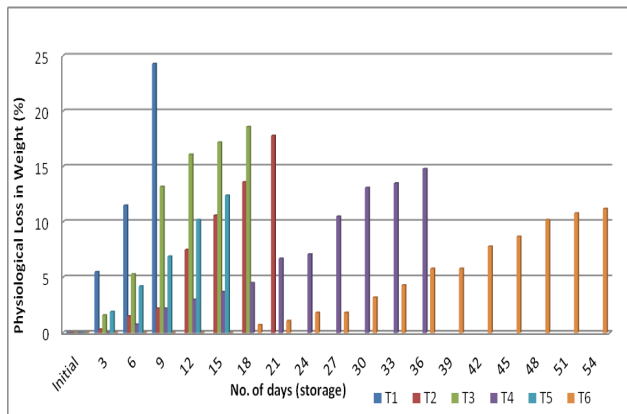


Fig. 1. Effect of surface coating and shrink-wrap packaging on physiological loss in weight (%) of mango cv. 'Neelum'.

conformity with those reported by (5) in 'Moovandan' mangoes treated with bee wax coating followed by modified atmosphere storage. Such effects due to wax coating could also happen due to blockage of lenticels and / or stomata (6). Individual shrink wrapping resulted in 4 to 5 times reduction in weight loss in 'Alphonso' and 9 to 10 times in 'Banganapalli' cultivars of mango as compared to non-wrapped fruits (7).

Respiration rate

Rate of respiration increased gradually in all the treatments, followed by a 'respiratory peak', which is a typical character as in all 'climacteric' fruits (Fig. 2). The initial CO₂ concentration in the head space of the samples ranged between 0.1 to 0.2 %. However, the rate of increase was significantly lower in the fruits subjected to wax coating and shrink wrapping, during storage. Further, storage in cool chamber also reduced the rate of respiration, irrespective of the treatments. Fruits subjected to waxing, followed by shrink-wrap packaging and subsequently stored in cool chamber recorded the lowest rate of respiration throughout storage and fruits in this treatment took 51 days to attain the 'respiratory peak' while the unwrapped fruits stored under ambient conditions reached the 'respiratory peak' after 9 days of storage. Fruits held under ambient conditions reached 'respiratory peak' earlier compared to their counterparts held in cool chamber, irrespective of the treatments. Surface coating followed by shrink wrapping may have acted as barriers to O₂ influx and the resultant modification of atmosphere due to higher levels of CO₂ may have reduced the respiratory activity. Reduction in respiratory activity of 'Moovandan' mango due to bee wax coating and modified atmosphere packaging was also reported (5). Similar findings were also reported in mango (8).

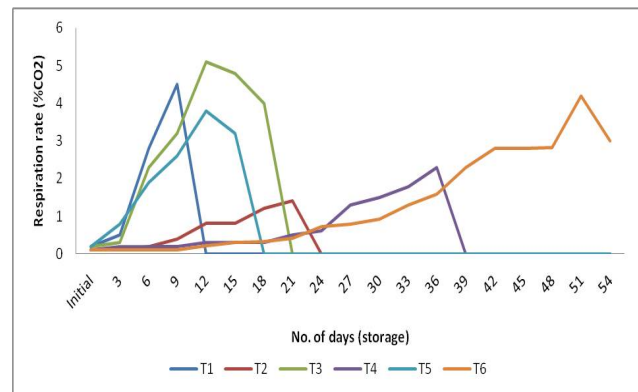


Fig. 2. Effect of surface coating and shrink-wrap packaging on respiration rate (% CO₂) of mango cv. 'Neelum'.

T1-Unwrapped (ambient storage); T2-Unwrapped (cold storage); T3-Waxed (ambient storage); T4-Waxed (cold storage); T5-Waxed and shrink wrapped (ambient storage); T6- Waxed and shrink wrapped (cold storage).

Further, storage at low temperature may also have retarded the metabolic activity of the fruits. Higher respiratory activity of mango cvs. 'Alphonso' and 'Banganapalli' under ambient conditions was also reported (9).

Shelf life

Surface coating of mango with Nipro Fresh, followed by shrink-wrap packaging and subsequent storage at low temperature prolonged shelf life of the fruits significantly compared to the control samples. Longest shelf life of 54 days was recorded in the fruits coated with wax, followed by shrink-wrap packaging and subsequent storage in cool chamber while the shortest (9 days) was observed in the uncoated and unwrapped fruits stored under ambient conditions (Fig. 3). However, surface coating of the fruits in combination with shrink-wrap packaging in trays made of arecanut leaf sheath and subsequent storage under ambient conditions was not beneficial in extending shelf life. This was mainly due to condensation and accumulation of moisture inside the packaged samples stored under ambient conditions and absorption of moisture by the trays made of arecanut leaf sheath, which resulted in the proliferation of the anthracnose disease causing fungus *Colletotrichum gloeosporioides*. This may be due to higher rates of transpiration in the wrapped samples stored under ambient conditions as air can hold more moisture at higher temperatures and the polymeric film acting as a barrier to the loss of moisture in the form of vapour. Condensation of water in modified atmosphere packaged bell peppers and mangoes was reported (10). Higher decay of 48.33 % was reported in pear cv. 'Nashpati', in tray over-wrapped with heat shrinkable film as compared to 30.0 % in individual fruit wrapping (11). However, fruits coated with wax, followed by shrink-wrap packaging extended shelf life significantly at low temperature, compared to all other treatments. This may be due to the lower metabolic activity induced due to passive modification of atmosphere through waxing and shrink wrapping. Storage in cool chamber may have further reduced the respiratory activity. This finding is in consonance with those earlier studies reported in 'Alphonso' (12) and in 'Alphonso' and 'Banganapalli' mangoes (7).

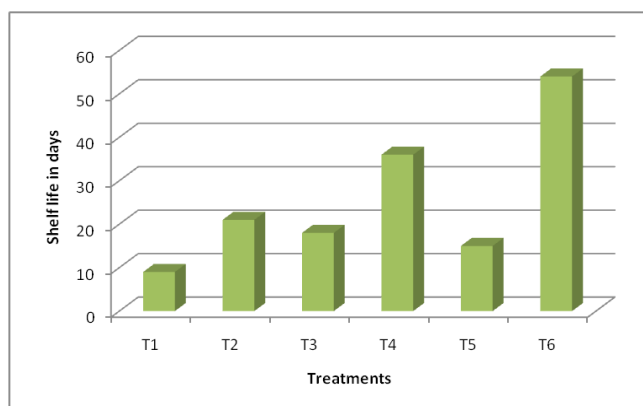


Fig. 3. Effect of surface coating and shrink-wrap packaging on shelf life (days) of mango cv. 'Neelum'.

T1-Unwrapped (ambient storage); T2-Unwrapped (cold storage); T3-Waxed (ambient storage); T4-Waxed (cold storage); T5-Waxed and shrink wrapped (ambient storage); T6- Waxed and shrink wrapped (cold storage).

Fruit firmness

Firmness of the fruits at the time of harvest was 0.87 kg cm^{-2} and all the treatments showed a steady decline in firmness during storage (Fig. 4). Surface coating with Nipro Fresh alone and combined treatment of wax along with shrink-wrap packaging of mango fruits of cv. 'Neelum' retained significantly higher levels of firmness under both ambient and low temperature storage, compared to the uncoated and unwrapped fruits (control). Storage in cool chamber resulted in higher retention of firmness compared to the samples held under ambient conditions. Higher retention of firmness due to wax treatment may be due to reduction in transpiration rates as a result of blockage of lenticels and/ or stomata. Significant reduction in fruit firmness of egg plant due to Carnauba wax treatment and subsequent packaging in polypropylene pouches, compared to the

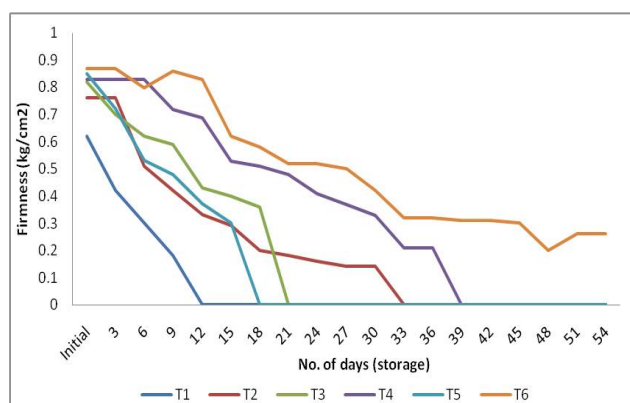


Fig. 4. Effect of surface coating and shrink-wrap packaging on firmness (kg cm^{-2}) of mango cv. 'Neelum'.

T1-Unwrapped (ambient storage); T2-Unwrapped (cold storage); T3-Waxed (ambient storage); T4-Waxed (cold storage); T5-Waxed and shrink wrapped (ambient storage); T6- Waxed and shrink wrapped (cold storage).

unpacked fruits (13). Further, combined treatment of mango fruits with wax and shrink-wrap packaging may have modified the atmospheric gases surrounding the produce leading to reduction in metabolic activities, particularly solubilisation of proto pectin into pectin. This solubilisation of proto

pectin was further reduced by storage at low temperature due to retarded activity of pectin degrading enzymes like pectin methyl esterase and polygalacturonase. These results are in conformity with those reported in 'Alphonso' mangoes (12).

Total soluble solids (TSS)

Total soluble solids of mango fruits rose in all the samples, irrespective of treatments and storage conditions (Fig. 5). However, wax coating and shrink-wrap packaging, separately and in combination resulted in lower levels of TSS. Fruits stored under ambient conditions retained significantly higher levels of TSS compared to low temperature storage. TSS content rose to 14.0° Brix after 9 days of storage in the control samples stored under ambient conditions, whereas it was 16.0° Brix , after 54 days in the fruits coated with wax, followed by shrink-wrap packaging and held in cool chamber. Rise in TSS content of fruits during storage may be due to conversion of starch into sugars. Lower levels of TSS in wax coated and shrink-wrapped fruits may be due to lower rates of metabolic activity. Further, storage at low temperature may have retarded the activity of amylase enzyme involved in the conversion of starch to sugars. Similar findings were also reported (7) in 'Alphonso' and 'Banganapalli' mangoes subjected to individual shrink wrapping. Lower levels of TSS due to combined treatment of bee wax and LDPE packaging was reported in 'Moovandan' mangoes (5).

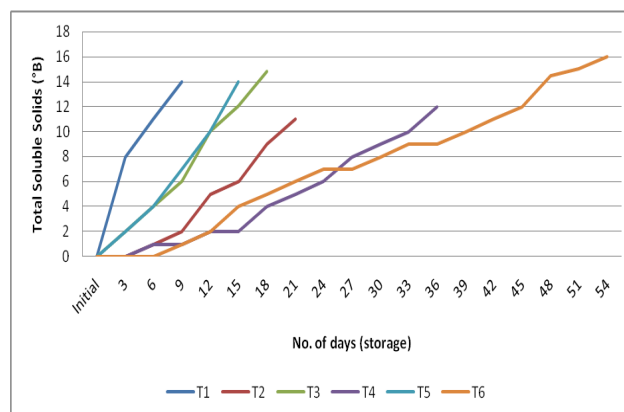


Fig. 5. Effect of surface coating and shrink-wrap packaging on total soluble solids ($^\circ \text{Brix}$) of mango cv. 'Neelum'.

T1-Unwrapped (ambient storage); T2-Unwrapped (cold storage); T3-Waxed (ambient storage); T4-Waxed (cold storage); T5-Waxed and shrink wrapped (ambient storage); T6- Waxed and shrink wrapped (cold storage).

Titrateable acidity

The initial titrateable acidity of mango cv. 'Neelum' was 0.92% (Table 1). A downward trend in titrateable acidity was observed in all the samples throughout storage. Fruits coated with wax, followed by shrink wrapping retained higher levels of acidity compared to the uncoated and unwrapped samples. Fruits held in cool chamber had higher levels of acidity than those stored under ambient conditions. Titrateable acidity declined to 0.28% in the uncoated and unwrapped fruits after one week of storage under ambient conditions, while it was 0.24% in the wax coated fruits subjected to shrink-wrap packaging and subsequently stored at low temperature, after 54 days. Decrease in titrateable acids during storage may

be attributed to utilization of organic acid in pyruvate decarboxylation reaction occurring during the ripening process of fruits (14). Retention of higher levels of acidity in the waxed fruits subjected to shrink-wrap packaging may be due to lower rates of biochemical reactions in these samples. Further, storage at low temperature may also have retarded the rate of metabolic activities. Retention of higher

ascorbic acid retention were also reported in individually shrink wrapped 'Alphonso' and 'Banganapalli' mangoes (7).

Total phenols

Mango fruits of cv. Neelum had an initial total phenol content of 85.0 mg100g⁻¹ (Table 3). Total phenols in all the samples fell with the advancement of storage

Table 1. Effect of surface coating and shrink-wrap packaging on titratable acidity (%) of mango cv. 'Neelum'

Treatments	Initial	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week
T1	0.92	0.28*	0.00	0.00	0.00	0.00	0.00	0.00
T2	0.92	0.51	0.49	0.21*	0.00	0.00	0.00	0.00
T3	0.92	0.75	0.42*	0.00	0.00	0.00	0.00	0.00
T4	0.92	0.76	0.56	0.28	0.21*	0.2	0.00	0.00
T5	0.92	0.45	0.21*	0.00	0.00	0.00	0.00	0.00
T6	0.92	0.64	0.56	0.28	0.28	0.27	0.24	0.24*
CV	1.087	1.77	2.456	5.51	7.07	7.37	10.206	10.206
CD (5%)	NS	0.018	0.016	0.013	0.01	0.01	0.007	0.007

NS-Non-significant; *Unmarketable; T1-Unwrapped (ambient storage); T2-Unwrapped (cold storage); T3-Waxed (ambient storage); T4-Waxed (cold storage); T5-Waxed and shrink wrapped (ambient storage); T6- Waxed and shrink wrapped (cold storage)

levels of acidity in Nipro Fresh coated kinnow mandarin was also reported (15). Similar trends in titratable acidity of individually shrink wrapped 'Alphonso' and 'Banganapalli' mangoes were also reported (7).

Ascorbic acid

Initial ascorbic acid content of mango cv. 'Neelum' was 72.0 mg100g⁻¹ (Table 2). Ascorbic acid content showed a downward trend throughout storage. However, fruits coated with Nipro Fresh and subjected to shrink-wrap packaging retained significantly higher levels of ascorbic acid, under ambient and low temperature conditions, compared to the uncoated and unwrapped samples under both storage conditions. Ascorbic acid content of uncoated and unwrapped fruits under ambient conditions declined to 28.86 mg100g⁻¹ after one week of storage, while the fruits coated with Nipro Fresh, followed by shrink-wrapping held at cool chamber retained 45.0 mg100g⁻¹, after seven weeks. Higher ascorbic acid content in waxed fruits followed by shrink wrapping may be due to the lower rates of respiration in these samples induced by low permeability to oxygen and subsequent retardation in the activity of oxidative enzymes responsible for ascorbic acid degradation, compared to the uncoated and unwrapped fruits. Storage of fruits in cool chamber may have further repackaging held in cool chamber retained 45.0 mg100g⁻¹, after seven weeks. Higher retention of vitamin C in cherries and strawberries coated with chitosan and chitoooligosaccharide was reported (16) during refrigerated storage. Similar trends in

period. However, Nipro Fresh coated fruits, separately and in combination with shrink-wrap packaging retained significantly higher levels of phenols. Further, storage at low temperature also prevented the loss of phenols. Total phenols in the uncoated and unwrapped samples (control) fell to 60.0 mg100g⁻¹, after one week of storage under ambient conditions, while the fruits coated with Nipro Fresh, followed by shrink wrapping and stored in cool chamber retained 50.0 mg100g⁻¹, after seven weeks. Decline in phenols with the advancement in maturity may be due to its polymerization to insoluble compounds, resulting in a reduction in astringency in the fruits. Fall in phenolic compounds during storage and ripening was reported in 'Hom Thong' banana (17). Higher retention of phenols in the waxed and wrapped fruits may be due to lower rates of biochemical reactions in these fruits. Storage at low temperature may have also retarded the degradation of phenols due to reduction in the activity of the enzyme, polyphenol oxidase. Similar trends were reported in 'Mas' banana stored in polybags (18).

Total carotenoids

Mango cv. 'Neelum' had a total carotenoid content of 0.2 mg100g⁻¹ (Table 4) at the time of harvest. The total carotenoid content rose with the advancement of maturity during storage. Significantly higher levels of carotenoids were seen in the samples stored under ambient conditions. Fruits held in cool chamber retained significantly lower levels of carotenoids, irrespective of treatments. Fruits coated with Nipro

Table 2. Effect of surface coating and shrink-wrap packaging on ascorbic acid (mg100g⁻¹) of mango cv. 'Neelum'

Treatments	Initial	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week
T1	72	28.86*	0.00	0.00	0.00	0.00	0.00	0.00
T2	72	50	57.6	57.6*	0.00	0.00	0.00	0.00
T3	72	52	62.4*	0.00	0.00	0.00	0.00	0.00
T4	72	65	67.2	67.2	51.6	41.6*	0.00	0.00
T5	72	57.6	38.4*	0.00	0.00	0.00	0.00	0.00
T6	72	60	67.2	67.2	63.5	55.3	47	45*
CV	1.389	1.749	1.871	2.21	3.01	3.575	5.212	5.443
CD (5%)	NS	1.626	1.624	1.258	1.027	1.027	0.726	0.726

NS-Non-significant; *Unmarketable; T1-Unwrapped (ambient storage); T2-Unwrapped (cold storage); T3-Waxed (ambient storage); T4-Waxed (cold storage); T5-Waxed and shrink wrapped (ambient storage); T6- Waxed and shrink wrapped (cold storage)

Table 3. Effect of surface coating and shrink-wrap packaging on total phenols (mg100g⁻¹) of mango cv. 'Neelum'

Treatments	Initial	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week
T1	85	60*	0.00	0.00	0.00	0.00	0.00	0.00
T2	85	80	75*	65*	0.00	0.00	0.00	0.00
T3	85	65	55*	0.00	0.00	0.00	0.00	0.00
T4	85	80	75	70	65	45*	0.00	0.00
T5	85	75	65*	0.00	0.00	0.00	0.00	0.00
T6	85	85	85	80	75	60	55	50*
CV	1.176	1.348	1.543	1.973	2.474	3.299	4.454	4.899
CD (5%)	NS	1.779	1.624	1.258	1.027	1.027	0.726	0.726

NS-Non-significant; *Unmarketable; T1-Unwrapped (ambient storage); T2-Unwrapped (cold storage); T3-Waxed (ambient storage); T4-Waxed (cold storage); T5-Waxed and shrink wrapped (ambient storage); T6- Waxed and shrink wrapped (cold storage)

Table 4. Effect of surface coating and shrink-wrap packaging on total carotenoids(mg100g⁻¹) of mango cv. 'Neelum'

Treatments	Initial	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week
T1	0.2	1.680*	0.00	0.00	0.00	0.00	0.00	0.00
T2	0.2	0.380	0.960	1.060*	0.00	0.00	0.00	0.00
T3	0.2	0.600	1.850*	0.00	0.00	0.00	0.00	0.00
T4	0.2	0.218	0.505	0.820	1.040	1.380*	0.00	0.00
T5	0.2	0.390	0.820*	0.00	0.00	0.00	0.00	0.00
T6	0.2	0.217	0.501	0.810	0.940	0.980	1.070	1.210*
CV	0.5	1.719	5.384	9.197	1.750	1.468	2.289	2.024
CD (5%)	NS	0.018	0.074	0.073	0.01	0.01	0.007	0.007

NS-Non-significant; *Unmarketable; T1-Unwrapped (ambient storage); T2-Unwrapped (cold storage); T3-Waxed (ambient storage); T4-Waxed (cold storage); T5-Waxed and shrink wrapped (ambient storage); T6- Waxed and shrink wrapped (cold storage)

Fresh in combination with shrink-wrap packaging and held in cool chamber retained the lowest levels of carotenoids throughout storage. Carotenoid content of the uncoated and unwrapped samples rose to 1.68 mg100g⁻¹, after one week of storage whereas the fruits coated with Nipro Fresh, followed by shrink-wrap packaging and held in cool chamber retained only 1.21 mg100g⁻¹, after seven weeks. Higher levels of carotenoids in the samples stored under ambient conditions may be due to higher rates of metabolic activities at higher temperature. Reduction in biochemical reactions in the wax coated fruits in combination with shrink wrapping and low temperature storage may have led to lower levels of carotenoids in these samples. Retention of significantly lower levels of carotenoids in individually shrink wrapped 'Alphonso' mango with LDPE film was also reported (7). Elevated CO₂ concentration inhibits ethylene synthesis which, in turn, influences chlorophyll breakdown. Low levels of O₂ also inhibit ethylene production (19).

Conclusion

The findings of the study reveal that the fruits of mango cv. 'Neelum', when coated with the wax Nipro Fresh, followed by shrink wrap packaging with polyolefin film of 25 μ thickness in trays made of areca nut leaf sheath is an ideal technique for extending shelf life of this mango cultivar. Harvesting the fruits at 110 days after fruit set, followed by sanitization treatments with chlorine and alum, and then dipping in the wax Nipro Fresh containing Carbendazim and then precooling at 12-13 °C for 8 hours and subjecting the pre-cooled fruits to shrink-wrap packaging with polyolefin film in areca nut leaf sheath trays and subsequently holding these fruits in a cool chamber at 12-13 °C and 85-90 % relative humidity, could prolong the shelf life of the fruits up to 54 days. This technique can be adopted as a viable

practice of post harvest handling to extend the availability and to maintain quality of mango cv. 'Neelum', which is the last commercial variety to attain maturity in the Indian State of Kerala, coinciding with the onset of South West monsoon which adversely affects the fruit quality. Occurrence of traces of the wax and fungicides in the flesh of fruit needs to be studied in the future experiments.

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Authors' contributions

SG conceived and carried out the experiment with the supervision of MJ. SJ, DJ and KS assisted in the analysis of quality parameters and statistical analysis. The manuscript was written and edited by SG.

Conflict of interests

Authors do not have any conflict of interests to declare.

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