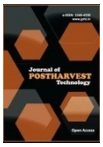

Journal of Postharvest Technology
2023, **11**(1): 105-114
www.jpht.in

RESEARCH ARTICLE

Effect of novel eco-friendly coating and packaging on quality and shelf life of Khasi mandarin (*Citrus reticulata* Blanco)

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Received: 11.09.2022 Accepted: 22.12.2022

ABSTRACT

Khasi mandarin is commercially grown in northeast India and has enormous export potential. However, inadequate storage structures and handling units with poor transport connectivity in the region are major setbacks to satisfy the growing demands. The experiment was conducted at Nagaland University, Medziphema campus, to study effect of coating and packaging on quality and shelf life of khasi mandarin fruits packed in T_0: (Control), T_1: (*Aloe vera* gel + Brown paper bag), T_2: (*Aloe vera* gel +Aluminium container), T_3: (*Aloe vera* gel + Cling wrap), T_4: (*Aloe vera* gel + Cardboard box), T_5: (*Aloe vera* gel + Polythene bag), T_6: (Coconut oil + Brown paper bag), T_7: (Coconut oil + Aluminium container), T_8: (Coconut oil + Cling wrap), T_9: (Coconut oil + Cardboard box and T_{10}: (Coconut oil + Polythene bag) following CRD with three replications. Treatments were analysed at every 5 days interval stored at ambient temperature for 50 days. Coconut oil + Cling wrap (T_8) showed the minimum PLW (7.25%), maximum shelf life (70days) and maintained the biochemical properties like TSS (11.50° Brix), titratable acidity (0.71%), total sugar (7.37%) and ascorbic acid (32.27mg/100g pulp) throughout storage period. This might be a potential pathway for edible and eco-friendly coating that can be used diversely in the field of postharvest shelf-life extension with minimal losses in quality.

Keywords: Khasi mandarin, Coating, Packaging, Quality, Shelf life

Citation: Theunuo, K., Sema, A. and Sarkar, A. 2023. Effect of novel eco-friendly coating and packaging on quality and shelf life of Khasi mandarin (*Citrus reticulata* Blanco). *Journal of Postharvest Technology,* **11**(1): 105-114.

INTRODUCTION

The northeast India is an important part of Indo-Burma biodiversity hotspot and this region is regarded as one of the centre of origin of various citrus species (Singh et al., 2016). The area and production of mandarin in India is estimated to be approximately 480 thousand Ha and 6368 thousand MT respectively (Anon, 2020). Among citrus, khasi mandarin (*Citrus reticulata* Blanco) is regarded as one of the most widely cultivated and important commercial fruit crops of northeast India. Postharvest treatments play a significant role in extending shelf life of citrus fruits (Rokaya et al., 2016). Citrus growers experienced fruit waste of about 34% in total activities (Hanif and Ashari, 2021). Postharvest losses of citrus can reach up to 30% of the total production and up to 50% in under developed countries (Strano et al., 2017). A crop loss during harvesting,

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ISSN: 2348-4330

post-harvest activities, handling and storage were about 5.8% to 18.1% (Jha et al., 2016). Hence, treatments initially from the harvesting to marketing level is very essential. Conventional postharvest treatments have raised important health and environmental issues. Therefore, an increasing need to find out non-polluting alternatives to be used for preservation of harvested citrus fruit is a wake-up call. Alternative, eco-sustainable or organic postharvest treatments are need of the hour. Eco-friendly coating and packaging are interesting emerging technology that promotes enhancing the shelf life through a controlled release of the antimicrobial compounds through coatings. New eco-friendly solutions would offer the opportunity to eliminate chemically synthesized fungicides to preserve natural qualities of fresh citrus fruits after harvest and extend their shelf life (Strano et al., 2017). Non perforated polymeric films such as cling film, shrink film, LDPE, HDPE creates a modified atmosphere within the package which helps in enhancing shelf life of fruits (Adhikary et al., 2020). Application of thin layers of edible coating onto fruit surface helps in modification of inner environment of fruit which causes similar effect to the modified atmospheric storage helpful to retard water loss, reduces skin damage caused by friction, changes in gaseous composition, moisture content, volatile aromas and transport of solutes from fruits enhancing cosmetic appearance and shelf life and decreasing repining process (Adhikary et al., 2020). Edible coating application on fruits block the pores within and reduces respiration and creates a modified atmosphere, thus improve postharvest quality (Kader, 2005). *Aloe vera* gel dip coating encouraged to reduce weight, minimising physiochemical alterations, decay losses and extending shelf life in papaya, figs and litchi fruits (Ghoora and Srividya, 2020). Edible coating of fruits with virgin coconut oil is an emerging research area in postharvest due to its anti-ageing properties and anti-fungal, anti-viral, anti-bacterial functions (Nasrin et al., 2020). Coconut oil coating closed opening of stomata and lenticels thus reducing transpiration, respiration rate and reduced microbial activities (Bisen et al., 2012). With the lack of proper post-harvest management units and the emerging need to find key to eco-friendly coating material for health-conscious consumers, the research has been planned out with the objectives to study the effect of coating and packaging on the quality and shelf life of Khasi mandarin.

MATERIALS AND METHODS

The experiment was conducted in the laboratory of Department of Horticulture, SASRD, Nagaland University, Medziphema campus during 2021. Fruits were harvested from Rusoma village, Kohima with a small pedicel intact of each fruit with the help of secateurs from the orchard. The harvested fruits were collected and kept in shade to remove field heat and carefully packed in plastic stacks provided with paper cushioning in between layers to avoid any physical injury during transportation. The experiment comprised of T_0 (Control), T_1 (*Aloe vera* gel + Brown paper bag), T_2 (*Aloe vera* gel +Aluminium container), T_3(*Aloe vera* gel + Cling wrap), T_4 (*Aloe vera* gel + Cardboard box), T_5 (*Aloe vera* gel + Polythene bag), T_6 (Coconut oil + Brown paper bag), T_7 (Coconut oil + Aluminium container), T_8 (Coconut oil + Cling wrap), T_9 (Coconut oil + Cardboard box) and T_{10} (Coconut oil + Polythene bag) laid out at CRD with three replications. Fruits were properly washed with clean tap water and allowed to dry under the fan for 3 hours inside the laboratory. Aloe vera leaves were collected, properly washed and gel matrix separated from the outer cortex. The colourless hydroparenchyma was grinded in blender and filtered to remove fibres. 75ml aloe gel was added in 25 ml distilled water and mixed in blender and fruits were dipped for 10 minutes. Virgin coconut oil was purchased from the market. It was placed in a beaker and stirred in hot water bath until melted and applied with a soft brush on surface of fruit. Initial physical and chemical observation were taken and then treated with coating materials. Fruits were stored at room temperature and analysed for its physical and chemical parameters every 5 days interval till 50th day. PLW was calculated by weight difference between initial and specific time interval divided by initial weight and finally denoted by percentage. Shelf life of fruit was determined by counting the number of days from the day of coating and packaging till the day

fruit samples became unmarketable (appearance, damage, rotting etc). The TSS calculated using ERMA handheld refractometer. Titratable acidity, total sugar and ascorbic acid were estimated following the method as suggested by Ranganna (1986).

RESULTS AND DISCUSSION

Physiological loss of weight (PLW)

PLW increased with prolonged storage duration irrespective of various treatments in Table 1. From 5th day till 50th day, Control (T_0) was recorded to have the highest weight loss from 5.37% to 40.63% whereas the lowest was recorded in coconut oil + cling film (T_8) from 1.94% to 12.65%. The mean PLW was highest in control (40.63%) whereas the lowest was recorded in coconut oil + cling film (7.25%). It was observed that various treatments had significant effect on PLW on khasi mandarin fruits. Loss in weight might be due to evapo-transpiration, respiration and degradation processes that occurred with progress of storage period (Kaur et al., 2014).

Table 1. Effect of various treatments on PLW (%) in khasi mandarin during storage

Treatments	Days of storage										
	5	10	15	20	25	30	35	40	45	50	Mean
T_0: Control	5.37	10.61	14.88	19.66	24.28	27.92	31.34	35.11	37.51	40.63	24.73
T_1: *Aloe vera* gel + Brown paper bag	4.19	8.67	12.40	15.92	20.43	23.10	25.36	28.37	30.89	33.04	20.24
T_2: *Aloe vera* gel +Aluminium container	2.86	5.44	6.76	8.29	10.94	13.02	15.46	17.56	18.84	21.44	12.06
T_3: *Aloe vera* gel + Cling wrap	2.74	4.48	6.32	8.06	9.31	11.57	12.90	14.70	16.37	18.27	10.47
T_4: *Aloe vera* gel + Cardboard box	3.56	7.25	10.47	14.56	17.32	19.83	22.36	25.54	28.16	30.93	18.00
T_5: *Aloe vera* gel + Polythene bag	2.27	4.11	6.66	8.78	9.81	11.35	12.64	13.63	14.98	16.39	10.06
T_6: Coconut oil + Brown paper bag	4.11	6.81	9.54	12.94	15.08	17.28	20.13	22.28	24.59	26.79	15.95
T_7: Coconut oil + Aluminium container	2.46	4.90	7.41	9.18	10.87	12.95	14.13	15.65	16.98	18.71	11.32
T_8: Coconut oil + Cling wrap	1.94	3.24	4.46	5.66	6.76	7.69	8.62	10.02	11.48	12.65	7.256
T_9: Coconut oil + Cardboard box	3.28	6.06	8.39	10.69	12.97	14.46	16.78	20.46	22.20	24.80	14.01
T_{10}: Coconut oil + Polythene bag	2.53	4.89	7.00	9.54	10.86	12.41	13.66	15.48	15.52	19.52	11.14
S.Em ±	0.51	0.61	0.62	0.82	0.85	1.09	1.02	0.99	0.96	0.92	-
CD at 5%	1.49	1.8	1.81	2.39	2.5	3.21	2.99	2.89	2.82	2.69	-

Maximum PLW was recorded in control (T_0) thar may be due to high rate of respiration resulting in shrivelling, loss of glossiness and browning (Kumar et al., 2003). Minimum weight loss in treated fruits may be due to the influence of coating and packaging that created a semi-permeable barrier (Randhawa et al., 2009). Similar results were reported by Kaur and Kaur (2020) who found that coating with coconut oil recorded minimum weight loss which might be due to the anti-senescence

property present in pure coconut oil which help to slow storage break down associated with slow respiration rate, transpiration rate and binding of the ethylene biosynthesis process in mandarin.

Shelf life

The data recorded for shelf life of fruits started from initial to final days of storage in response to various treatments in Fig 1. Strano et al. (2017) stated that citrus have relatively longer shelf life compared to other tropical fruits. Minimum shelf life (20 days) was observed in control (T_0) under normal condition, whereas, maximum shelf life (70 days) was observed in coconut oil + cling film (T_8). Fruits treated with eco-friendly edible coating material like virgin coconut oil and *Aloe vera* gel along with packaging materials like polythene, cardboard boxes, aluminium containers, cling wrap and paper bags were significantly found to extend shelf life. Gallagher and Mahajan (2011) stated that rootstock, cultivar, pre-harvest practices, harvest conditions, maturity stage, operational efficiency, pre-cooling, treatments and storage conditions are important factors that affect the shelf life and quality. Kaur and Kaur (2020) reported that coconut oil might have closed the opening of stomata and lenticels resulting in reduction of transpiration and respiration rate and also the microbial activity leading to an increase in shelf life with good acceptability. A combined effect of lower respiration rate and decreased metabolic activity in cells of treated fruits may have extended shelf life of khasi mandarin in contrast to untreated fruits. Bhattaria and Shah (2017) reported that the fruits packed with plastic, newspaper and jute wrapping were found to have extended shelf life in mandarin.

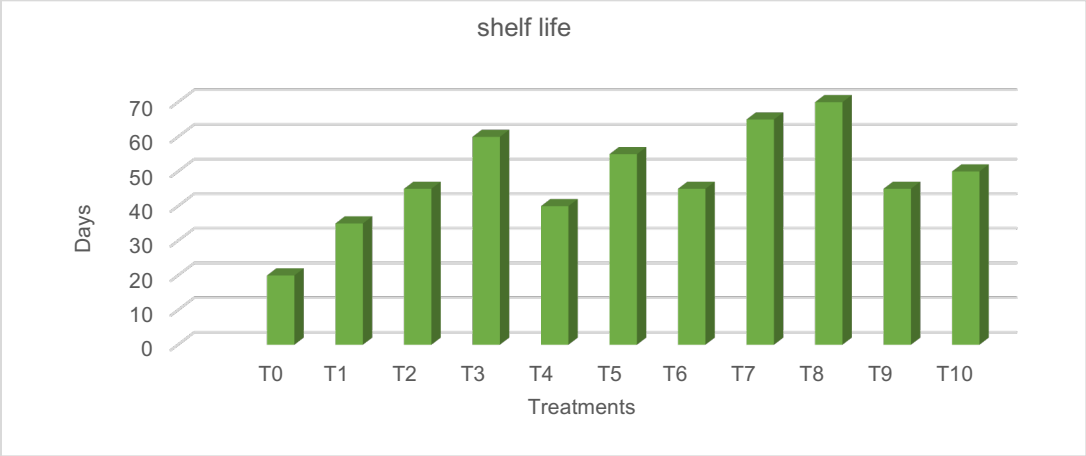

Fig 1. Effect of various treatments on shelf life (days) in khasi mandarin during storage

Total soluble solids (°Brix)

The analytical data showed an increase in TSS content with prolonged storage days in all the treatments in Table 2. Maximum TSS (13.18 ^{0}Brix) was recorded in control and the minimum (12.58 ^{0}Brix) was recorded in fruits treated with coconut oil + cling film which was at par with treatments, T_3, T_7 and T_5 with 12.61 ^{0}Brix, 12.65 ^{0}Brix and 12.68 ^{0}Brix respectively. The highest mean TSS of 11.99 ^{0}Brix was observed in control (T_0) and the lowest of 11.50 ^{0}Brix was in coconut oil + cling film (T_8). The minimum TSS may be due to the effect of coating and packaging that creates protective barrier around the fruit causing minimal water losses (Ahlawat et al., 2018). Kaur and Kaur (2020) reported that TSS in citrus increased for a period during storage that was associated to concurrent increase in sucrose content due to hydrolysis of insoluble polysaccharides into sugars. The gradual decrease at the end of storage days may be due to its consumption in evapo-transpiration and other

biochemical activities in the fruit (Kaur et al., 2017). Randhawa et al. (2018) stated that coating resulted in minimum TSS that advanced shelf life in kinnow mandarin. The results were in consonance of Barsha et al. (2021) who reported that treated materials created a physical barrier for transpiration losses in mandarin resulting in minimal TSS loss during storage.

Table 2. Effect of various treatments on TSS (^{0}Brix) in khasi mandarin during storage

Treatments	Days of storage											
	0	5	10	15	20	25	30	35	40	45	50	Mean
T_0: Control	10.57	10.87	11.17	11.51	11.70	11.97	12.27	12.61	12.87	13.22	13.18	11.99
T_1: *Aloe vera* gel + Brown paper bag	10.57	10.81	11.11	11.44	11.60	11.87	12.04	12.34	12.54	12.88	13.01	11.83
T_2: *Aloe vera* gel +Aluminium container	10.57	10.77	10.94	11.14	11.34	11.64	11.81	12.01	12.27	12.71	12.81	11.63
T_3: *Aloe vera* gel + Cling wrap	10.57	10.74	10.91	11.11	11.30	11.57	11.74	11.91	12.17	12.35	12.61	11.54
T_4: *Aloe vera* gel + Cardboard box	10.57	10.71	10.94	11.21	11.57	11.74	11.97	12.37	12.67	12.95	13.05	11.79
T_5: *Aloe vera* gel + Polythene bag	10.57	10.81	10.97	11.07	11.27	11.50	11.77	11.87	12.11	12.51	12.68	11.55
T_6: Coconut oil + Brown paper bag	10.57	10.84	11.04	11.34	11.60	11.84	12.07	12.31	12.64	12.91	13.08	11.85
T_7: Coconut oil + Aluminium container	10.57	10.74	10.91	11.17	11.37	11.60	11.84	11.97	12.37	12.48	12.65	11.61
T_8: Coconut oil + Cling wrap	10.57	10.71	10.87	11.07	11.24	11.40	11.67	11.81	12.14	12.38	12.58	11.50
T_9: Coconut oil + Cardboard box	10.57	10.81	10.81	11.17	11.40	11.67	11.91	12.11	12.44	12.78	12.88	11.68
T_{10}: Coconut oil + Polythene bag	10.57	10.77	10.84	11.11	11.37	11.70	11.94	12.21	12.47	12.75	12.91	11.70
SEm ±	0.08	0.05	0.05	0.06	0.05	0.06	0.05	0.08	0.07	0.09	0.06	-
CD at 5%	NS	NS	0.16	0.17	0.15	0.17	0.15	0.24	0.22	0.28	0.19	-

Titratable acidity

From the analytical data, titratable acidity was significantly decreased with prolonged storage period in Table 3. On 50th day, the lowest acidity was recorded in control fruits of 0.21% whereas the highest acidity (0.59%) was recorded in fruits treated with coconut oil and cling film. The mean titratable acidity during whole storage period was recorded lowest in control (0.49%) and the highest was in coconut oil + cling wrap (T_8) with 0.71%. It is evident from the data that control fruits rapidly decreased with storage time. This may be due to exhaustion of organic acids triggered by faster rate of ripening and respiration in fruits (Bhuyan et al., 2018). A gradual decrease in acidity among treated fruits might be due to the effect of coating and packaging that slowed down the respiration process (Joshi et al., 2020). Findings were in line with Nasrin et al. (2020) who reported a slight decrease in acidity during storage in kinnow mandarin.

Table 3. Effect of various treatments on titratable acidity (%) in khasi mandarin during storage

Treatments	Days of storage											
	0	5	10	15	20	25	30	35	40	45	50	Mean
T_0: Control	0.82	0.72	0.68	0.61	0.55	0.48	0.42	0.36	0.32	0.25	0.21	0.49
T_1: *Aloe vera* gel + Brown paper bag	0.82	0.77	0.70	0.62	0.59	0.53	0.46	0.42	0.39	0.34	0.30	0.54
T_2: *Aloe vera* gel +Aluminium container	0.82	0.76	0.72	0.68	0.62	0.60	0.55	0.51	0.48	0.43	0.40	0.59
T_3: *Aloe vera* gel + Cling wrap	0.82	0.80	0.78	0.76	0.74	0.70	0.66	0.62	0.59	0.57	0.53	0.69
T_4: *Aloe vera* gel + Cardboard box	0.82	0.74	0.70	0.66	0.60	0.53	0.48	0.44	0.40	0.36	0.32	0.55
T_5: *Aloe vera* gel + Polythene bag	0.82	0.80	0.76	0.72	0.68	0.66	0.62	0.57	0.53	0.51	0.49	0.65
T_6: Coconut oil + Brown paper bag	0.82	0.76	0.72	0.68	0.61	0.55	0.49	0.44	0.42	0.38	0.34	0.56
T_7: Coconut oil + Aluminium container	0.82	0.79	0.76	0.70	0.70	0.66	0.64	0.61	0.59	0.57	0.55	0.67
T_8: Coconut oil + Cling wrap	0.82	0.81	0.79	0.74	0.76	0.72	0.70	0.66	0.64	0.62	0.59	0.71
T_9: Coconut oil + Cardboard box	0.82	0.76	0.72	0.66	0.61	0.55	0.51	0.46	0.42	0.39	0.36	0.57
T_{10}: Coconut oil + Polythene bag	0.82	0.78	0.76	0.72	0.66	0.62	0.59	0.55	0.51	0.48	0.44	0.63
SEm ±	0.06	0.04	0.04	0.03	0.04	0.03	0.03	0.04	0.06	0.07	0.04	
CD at 5%	NS	NS	0.12	0.08	0.13	0.09	0.10	0.11	0.17	0.19	0.12	

Total sugar

The analytical data revealed that on 50th day of storage, maximum total sugar content was recorded in control (T_0) of 10.01% and minimum in T_8 (coconut oil + cling wrap) with 8.58% which was at par with treatments, T_5, T_7, T_9, T_{10}, T_3 and T_2 with 8.83%, 8.84%, 8.96%, 8.98%, 9.23% and 9.24% respectively in Table 4. The mean total sugar content was maximum in T_0 (control) with 8.47%, whereas minimum was in Coconut oil + Cling wrap (T_8) with 7.37%. Amongst the treated fruits, the least sugar content in treated fruits with coconut oil + cling wrap (T_8) might be due to maximum reduction in loss of moisture that was influenced by the synergistic effect of coconut oil coating and cling film with a thin permeability for respiration. Decline in sugar content at the end of storage in control fruits may be due to occurrence of complete hydrolysis and higher sugar content that induces rapid moisture losses and faster hydrolysis processes (Bhuyan et al., 2018). Findings were in line with Kaur and Kaur (2020) who reported that minimal total sugar might be due to delayed transpiration, respiration and ripening processes and also delayed activity in the conversion of polysaccharides into soluble sugars. Miri et al. (2018) stated that TSS in control increases rapidly and then starts declining at faster rate leading to development of flat taste.

Table 4. Effect of various treatments on total sugar (%) content in khasi mandarin during storage

Treatments	Days of storage											
	0	5	10	15	20	25	30	35	40	45	50	Mean
T_0: Control	6.36	6.93	7.41	7.79	8.11	8.45	8.95	9.37	9.68	10.17	10.01	8.47
T_1: *Aloe vera* gel + Brown paper bag	6.36	6.81	7.32	7.59	7.80	8.11	8.46	8.95	9.37	9.68	9.91	8.21
T_2: *Aloe vera* gel +Aluminium container	6.36	6.75	7.06	7.31	7.61	7.92	8.23	8.59	8.70	8.88	9.24	7.88
T_3: *Aloe vera* gel + Cling wrap	6.36	6.76	6.97	7.14	7.41	7.6	8.00	8.22	8.45	8.70	9.23	7.71
T_4: *Aloe vera* gel + Cardboard box	6.36	6.82	7.14	7.49	7.89	8.23	8.57	8.98	9.37	9.73	9.84	8.23
T_5: *Aloe vera* gel + Polythene bag	6.36	6.66	7.05	7.22	7.50	7.69	8.12	8.35	8.50	8.72	8.83	7.72
T_6: Coconut oil + Brown paper bag	6.36	6.82	7.22	7.42	7.59	7.89	8.34	8.76	9.1	9.40	9.68	8.04
T_7: Coconut oil + Aluminium container	6.36	6.68	6.81	7.14	7.31	7.59	7.91	8.23	8.50	8.70	8.84	7.64
T_8: Coconut oil + Cling wrap	6.36	6.6	6.74	7.05	7.14	7.31	7.41	7.69	8.03	8.23	8.58	7.37
T_9: Coconut oil + Cardboard box	6.36	6.76	7.05	7.31	7.6	7.91	8.00	8.37	8.62	8.87	8.96	7.80
T_{10}: Coconut oil + Polythene bag	6.36	6.74	6.97	7.32	7.50	7.79	7.92	8.23	8.59	8.82	8.98	7.74
SEm ±	0.41	0.22	0.13	0.14	0.17	0.2	0.23	0.3	0.32	0.35	0.30	-
CD at 5%	NS	NS	0.37	0.41	0.51	0.59	0.68	0.88	0.95	1.03	0.91	-

Ascorbic acid (mg/100g of pulp)

The analytical data revealed that there was decrease in ascorbic acid content with increase in storage period in Table 5. On 50th day, minimum ascorbic acid content was recorded in control (14.5 mg/100g) and maximum ascorbic acid content retained in fruits treated with coconut oil + cling wrap (T_8) with 25.52 mg/100g. The mean lowest ascorbic was found in control (24.57mg) and the highest was in T_8 (coconut oil + cling wrap) with 32.27mg/100g. Singh et al. (2016) stated that decrease in ascorbic acid content may be due to utilization of organic acids during respiration or their conversion of sugars. The minimum conversion of sugar may be due to the effect of coating and packaging. Retention of ascorbic content in coated and packaged treated fruits might be due to the lesser degradation of ascorbic acid during storage (Rokaya et al., 2016). Results were in line with Nasrin et al. (2020) who reported that coconut oil alone or in combination with beewax coating found maximum ascorbic acid at the end of storage in lemons.

Table 5. Effect of various treatments on ascorbic acid (mg/100g pulp) content in khasi mandarin during storage

Treatments	Days of storage											
	0	5	10	15	20	25	30	35	40	45	50	Mean
T_0: Control	37.7	31.53	29.66	27.6	26.68	24.64	22.68	20.64	18.98	15.66	14.5	24.57
T_1: *Aloe vera* gel + Brown paper bag	37.7	32.10	30.26	28.8	27.26	26.88	24.84	23.50	22.54	20.88	18.56	26.34
T_2: *Aloe vera* gel +Aluminium container	37.7	33.25	30.85	30.6	29.66	28	27.54	26.94	25.51	23.78	22.62	28.61
T_3: *Aloe vera* gel + Cling wrap	37.7	34.97	33.22	32.4	31.9	30.24	29.16	28.66	27.29	26.1	24.36	30.45
T_4: *Aloe vera* gel + Cardboard box	37.7	32.68	31.44	29.4	28.48	27.44	26.46	25.8	24.32	22.62	20.88	27.71
T_5: *Aloe vera* gel + Polythene bag	37.7	34.4	33.82	33	32.48	31.36	30.78	29.81	28.72	27.84	24.94	31.35
T_6: Coconut oil + Brown paper bag	37.7	33.25	32.63	30	29.07	28.56	27	25.22	24.92	23.2	22.04	28.24
T_7: Coconut oil + Aluminium container	37.7	35.54	34.41	33.6	32.63	31.92	30.24	29.24	28.48	27.26	23.2	31.51
T_8: Coconut oil + Cling wrap	37.7	36.12	35.6	34.8	34.22	33.04	32.4	31.53	29.07	26.68	25.52	32.27
T_9: Coconut oil + Cardboard box	37.7	33.25	32.04	31.8	31.32	30.8	29.7	28.09	27.88	26.68	23.2	30.22
T_{10}: Coconut oil + Polythene bag	37.7	33.82	32.63	31.2	30.85	29.68	28.62	27.52	26.10	25.52	23.78	29.55
SEm ±	0.58	1.19	1.04	1.28	0.96	0.94	1.09	1.75	1.31	1.25	1.08	-
CD at 5%	NS	NS	3.05	3.76	2.82	2.76	3.2	5.15	3.86	3.66	3.16	-

CONCLUSION

From the present investigation, it could be concluded that Coconut oil + cling wrap was found to show better results in maintaining quality (PLW, TSS, titratable acidity, total sugar, ascorbic acid) and shelf life as compared to other treatments. Khasi mandarin can be safely stored for 70 days with acceptable quality and minimum spoilage with coconut oil + cling wrap treatment.

ACKNOWLEDGEMENT

The authors would like to thank the Department of Horticulture, SASRD, Nagaland University for providing the necessary facilities and infrastructures to conduct the experiment and analysis of samples.

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