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RESEARCH ARTICLE

Influence of essential oils and chitosan on quality attributes and shelf life of pineapple cv. Giant Kew at ambient storage

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ABSTRACT

Pineapple is one of the important tropical fruits of Bromeliaceae family widely cultivated, consumed, and exported from India. Being a fruit of tropical origin and as mostly traded in ambient conditions within country caused high post-harvest loss and low shelf life. Essential oils as proven antimicrobial agent along with chitosan, as a protective barrier were targeted to use for the experiment. The present investigation was conducted to study the influence of chitosan and essential oils viz. lemon grass oil and basil oil, on quality attributes and shelf life of pineapple cv. Giant Kew at ambient storage (temperature of 20-25℃ and relative humidity 65-85%). Results of the study revealed that the coating of pineapple with chitosan (1%) along with lemon grass oil (0.5%) at 15 days after storage was the most effective in maintaining weight loss (8.84%), per cent decrease in fruit length (2.58%) and fruit diameter (3.97%) with highest fruit firmness (41.79 N). The same treatment also recorded highest TSS (15.25ºBrix), TSS: Acid ratio (24.60), total sugar (7.41%), reducing sugar (6.13%) and ascorbic acid (24.54 mg 100g-1) content. Minimum fruit decay (6.67%) was observed in fruit treated with chitosan (1%) + lemon grass oil (0.5%) with maximum shelf life of 19.93 days.

Keywords: Basil oil, chitosan, lemon grass oil, pineapple, postharvest

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INTRODUCTION

Pineapple (*Ananas comosus*) is the only species belonging to Bromeliaceae family widely cultivated for commercial as well as nutritional fruit. Production occurs both in tropics and subtropics. It is the third most important fruit in the world after banana and citrus (Lobo and Siddiq, 2017). India is the fifth largest producer of pineapple in the world (Saloni et al., 2017). In India, pineapple is cultivated over an area of 102.96 thousand hectare with an annual production of 1705.76 thousand metric tonnes (Anon., 2018). Pineapples are often treated with fungicide to avoid the incidence of postharvest losses such as fruit rot and waxes to reduce water losses. The ideal temperature for storing pineapple is 7-10°C when ripen and 10-13°C when partially ripe at 90-95% relative humidity (Kader, 1992; Paul, 1992). Generally cold storage is preferred to reduce the unwanted quality changes and to enhance shelf-life of freshly harvested pineapples, but at temperature below 13°C pineapple becomes susceptible to chilling injury symptoms (Abdullah and Atan, 1983). At 10°C temperature, black heart symptoms appeared in the flesh of 'Smooth Cayenne' fruit (Stewert et al., 2002). At storage, postharvest treatment of fruits is done to avoid the incidence of pathogens. About 20-25% of fruits are decayed by pathogens during storage (Droby, 2006; Zhu, 2006; Singh and Sharma, 2007). The

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chilling injury symptoms have been controlled by using waxing treatment, modified atmosphere packaging, ascorbic acid and application of the ethylene inhibitor 1-methlcyclopropane (1-MCP) (Lobo and Siddiq, 2017).

Owing to health hazards in using of chemical fungicides, essential oil is much preferred. The essential oil obtained from plants show antimicrobial behaviour (Bosquez-Molina et al., 2010), eco-friendly and biodegradable properties (Tzortzakis and Economakis, 2007). Application of edible coatings is a promising alternative to improve the quality and extend shelf life of fresh and minimally processed produce. Chitosan possesses biochemical properties, inherent antifungal properties, enzyme activity (chitinase), and elicitation of phytoalexins and due to excellent film forming ability of chitosan it is proved to be effective at extending the shelf life of fruits and vegetables (Ibrahim et al., 2014). Further, biopolymer chitosan; is also used for postharvest shelf life maintenance and storage of tomato (Ghaouth et al., 1992), litchi (Zhang and Quantick, 1997), longan (Jiang and Li, 2001), grape (Meng et al., 2008), papaya (Ali et al., 2011) and guava (Hong et al., 2012) etc. fruits.

Therefore, the present investigation was taken up to study the effect of chitosan and essential oils on postharvest quality and shelf life of pineapple at ambient storage.

MATERIALS AND METHODS

Freshly harvested fruits of pineapple cv. Giant Kew were obtained from a local orchard near Reiek, Aizawl district of Mizoram for analysis. Fruits harvested were sorted according to shape, size, colour, fruit firmness, free from diseases and pests. Initially fresh mature green pineapple fruits were properly washed in running water to remove debris and then were allowed to air dry. Sample analysis was carried out in the Research Laboratory, Department of Horticulture, Aromatic and Medicinal Plants, School of Earth Sciences and Natural Resources Management, Mizoram University situated at Tanhril, Aizawl, Mizoram.

The experiment was laid out in complete randomized design (CRD) with 9 treatments and 5 replications which comprises of T1: Chitosan (1%), T2: Chitosan (2%), T3: Lemon Grass Oil (0.5%), T4: Basil Oil (0.5%), T5: Chitosan (1%) + Lemon Grass Oil (0.5%), T6: Chitosan (1%) + Basil Oil (0.5%), T7: Chitosan (2%) + Lemon Grass Oil (0.5%), T8: Chitosan (2%) + Basil Oil (0.5%), T9: Control (Water dipped).

Chitosan solution was prepared by adding requisite quantity of chitosan to distilled water mixed with acetic acid and maintained the pH at 5.6 using 1N NaOH. Then the chitosan solution was stirred thoroughly and mixed till it well to become a jelly like solution. Then respective essential oils were used. The essential oils used i.e. lemon grass oil and basil oil were pure and certified natural product of Mesmara Botanics Private Limited, Ramachandrapuram, Sangareddy District, Telangana, India. For respective essential oil, initially 2% stock solution was prepared using double distilled water and Tween 20 and further dilution was made with double distilled water to obtain required concentration of the selected essential oil for treatment. Further respective concentration of essential oil was used combined with chitosan for smearing the fruit in case of combined treatment, however for sole treatment it was singly applied. Control pineapple fruits were dipped in water and then air dried for further analysis. All sets of matured green pineapples across the treatment were kept on open shelves and the shelves were covered with perforated net for the entire period of storage at ambient condition (laboratory) with temperature range of 20 to 25ºC and relative humidity 65 to 85%.

Observations were recorded for different physical and biochemical parameters at 5 and 15 days after storage (DAS) on weight loss (using digital electronic balance), per cent decrease in fruit length and diameter (using digital slide caliper, thread and scale), fruit firmness (using digital penetrometer), juice content, fruit peel and flesh colour (digital handheld colour meter for L*, a*, b*), scoring of flesh translucency [score1: 100% opaque, score 2: opaque with slight translucent (less than 50%), score 3: opaque with moderate translucent (more than 50%), score 4: 100% translucent] and crown condition (score 1: good fresh and green, score 2: good with slightly yellow at the tips, score 3: moderate, dry tips and yellowing, score 4: severely infected, score 5: severe yellowing; Mandal et al., 2015). Determination of total soluble solids (TSS) using handheld refractometer, titratable acidity, total sugar and reducing sugar (AOAC, 1990), ascorbic acid, percentage of fruit decay were done. Optimum shelf life (days) of fruit under different treatment in room condition were evaluated depending on the visual observation of fruit decay, fruit physico – chemical parameters and spoilage and counting the days from harvest to the day with maximum visual score, edible and marketable quality (Mandal and Vanlalawmpuia, 2020; Moneruzzaman et al., 2009).

Analysis of variance (ANOVA) was performed to study the variation in the means of the parameters and statistical significance level were determined at $p \leq 0.05$.

RESULTS AND DISCUSSION

Physiological weight loss

Physiological weight loss increased with the duration of storage at room temperature. The percentage weight loss of pineapple samples exhibited significant variation due to different postharvest treatments at room temperature. After 5 days of storage, maximum percentage weight loss was observed in fruits at control (8.79 %) followed by fruits treated with T7 (chitosan 2% + basil oil 0.5%) (6.25%) and the lowest was recorded in the samples treated with T5 (chitosan 1% + lemon grass oil 0.5%) (3.61%) (Table 1). Similarly, at 15 DAS, the maximum weight loss was observed in control (23.47 %) followed by treatment with T7 (chitosan 2% + basil oil 0.5%) (15.72%) and the least percentage weight loss found at sample treated with T5 (chitosan 1% + lemon grass oil 0.5%) (8.84 %). Zhu et al. (2008) reported that the weight loss in fresh fruit is mainly due to transpiration and respiration that lead to loss of water content in fruit. It has been reported that chitosan effects more at delaying weight loss in banana and mango (Kittur et al., 2001) and strawberries (Ribeiro et al., 2007).

Table 1: Effect of postharvest treatments on physiological weight loss, decrease in fruit length and fruit diameter of pineapple

Treatments	Physiological Weight Loss (%)		Decrease in fruit length (%)		Decrease in fruit diameter (%)	
	5DAS	15 DAS	5DAS	15 DAS	5DAS	15 DAS
T1: Chitosan 1%	5.61	10.62	1.81	3.56	1.91	5.07
T2: Chitosan 2%	5.94	13.16	3.16	4.56	2.64	6.34
T3: Lemon Grass Oil 0.5%	4.39	9.16	1.69	3.26	1.17	4.11
T4: Basil Oil 0.5%	6.11	12.87	2.58	4.78	2.35	5.67
T5: Chitosan 1%+ Lemon Grass Oil 0.5%	3.61	8.84	1.09	2.58	0.62	3.97
T6: Chitosan 1% + Basil Oil 0.5%	5.67	11.54	2.25	3.87	1.95	5.26
T7: Chitosan 2%+ Lemon Grass Oil 0.5%	5.78	12.32	2.38	4.28	2.16	5.56
T8: Chitosan 2% + Basil Oil 0.5%	6.25	15.72	3.57	4.34	2.87	5.95
T9: Control	8.79	23.47	5.16	7.74	4.95	8.32
SEm±	0.6671	0.7185	0.3679	0.4628	0.4061	0.5216
CD at 5%	0.9445	1.0173	0.5209	0.6552	0.5749	0.7385

Percent decrease in fruit length and fruit diameter

When stored at room temperature, the length and diameter of pineapple gradually shortened with the increase in storage days due to shrinkage. Minimum percent decrease in fruit length was recorded in T5 (chitosan 1% + lemon grass oil 0.5%) at 5 DAS (1.09 %) and 15 DAS (2.58 %). Also, fruits treated with T3 (lemon grass oil 0.5%) at 5 DAS (1.17%) and T5 (chitosan 1% + lemon grass oil 0.1%) at 15 DAS (3.97%) recorded minimum percent decrease in fruit diameter (Table 1). Maximum percent decrease in fruit length (5.16% and 7.79%) and fruit diameter (4.95 % and 8.32%) was recorded in control at 5 DAS and 15 DAS. Hazbavi et al. (2015) reported that the decrease in length and diameter of fruits is due to loss of water by transpiration and respiration. Coating with chitosan and essential oil made a protective barrier while hindered the surface moisture loss from fruits and may consequently have reduced the rate of fruit shrinkage.

Fruit firmness

Firmness of the fruit decreased as the period of storage increased. Fruits treated with T5 (Chitosan 1% + Lemon grass Oil 0.5%) recorded highest firmness of 46.85 N and 41.79 N at 5 and 15 DAS. At 5 and 15 DAS, it was observed that control had the lowest fruit firmness 34.06 N and 29.86 N, respectively (Table 2). The ripening and softening of fruit usually go along with catabolism of cell wall polysaccharides (hemicellulose). The breakdown of polymeric carbohydrates, especially pectic substances and hemiculluloses, weaken the cell walls and led to the reduction of firmness in fruit (Othman, 2008). The positive effect of chitosan was reported for Murcott (Chien et al., 2007a), papaya (Ali et al., 2011) and Guava (Keqian et al., 2012). Hassanein et al. (2018) reported that lemongrass oil postharvest utilization had maintained the fruit firmness in guava.

Juice content

The juice content of the stored pineapple was recorded highest in control at 5 and 15 DAS, 66.20% and 71.50% , respectively (Table 2) followed by T8 (Chitosan 2% + Basil oil 0.5%), 60.40% at 5 DAS and 67.40% at 15 DAS. The least amount of juice content was observed in T5 (Chitosan 1% and Lemon grass 0.5%) at 5 and 15 DAS (50.40% and 57.80%).

Table 2: Effect of postharvest treatments on fruit firmness, juice content and crown condition

Treatments	**Firmness (N)**		**Juice Content (%)**		**Crown Condition (Average Score)**	
	5DAS	**15 DAS**	**5DAS**	**15DAS**	**5DAS**	**15DAS**
T1: Chitosan 1%	44.56	38.81	51.80	60.80	1.20	6.67
T2: Chitosan 2%	36.72	34.46	59.40	65.20	1.40	20.00
T3: Lemon Grass Oil 0.5%	45.59	39.62	51.60	59.40	1.20	13.33
T4: Basil Oil 0.5%	38.76	36.15	59.80	64.40	1.20	20.00
T5: Chitosan 1%+ Lemon Grass Oil 0.5%	46.85	41.79	50.40	57.80	1.00	6.67
T6: Chitosan 1% + Basil Oil 0.5%	41.88	38.35	52.60	62.70	1.40	13.33
T7: Chitosan 2%+ Lemon Grass Oil 0.5%	41.66	37.32	54.80	62.80	1.00	20.00
T8: Chitosan 2% + Basil Oil 0.5%	39.34	35.85	60.40	67.40	1.60	26.67
T9: Control	34.06	29.86	66.20	71.50	1.60	40.00
SEm±	0.7851	0.7798	0.6576	0.6394	**-**	**-**
CD at 5%	1.1115	1.1041	0.9310	0.9052	**-**	**-**

Crown condition of stored pineapple

It was observed that crown condition was good with slight development of yellow colour at tip in most of the treatments up to 5 DAS. The crown condition score was recorded highest for the control with 2.60 (slightly yellow at the tip) and the lowest was of T1 (Chitosan 1%), with the score of 1.20 (slightly fresh and green) at 15 DAS (Table 2). Chitosan coating which may have reduced the moisture loss from the leaf surface and resulted in prolonged freshness.

Fruit peel and flesh colour

Fruits coated with T5 (chitosan 1% + lemon grass oil 0.5%) has the dark olive-green peel (L: 28.09, a: 0.01, b: 7.98); whereas, complete orange peel was found in control (L: 32.10, a: 28.39, b: 31.80) at 15 DAS (Table 3). It was also observed that fruits coated with T5 (Chitosan 1%+ Lemon Grass Oil 0.5%) has the lightest pale white flesh (L: 67.21, a:-1.78, b:15.80) and control have fully golden yellow colour flesh (L: 52.46, a:1.99, b: 33.16) which indicates complete ripening. Longer storage period of fruits and vegetables cause degradation of chlorophyll, exposing the lighter yellow pigments (Moalemiyan and Ramaswamy, 2012). Basumatary et al. (2021) found that coating pineapple with chitosan had delayed the turning of colour from green to yellow.

Table 3: Effect of postharvest treatments on peel colour, flesh colour and flesh translucency

Treatments	Peel colour at 15 DAS			Flesh colour at 15 DAS			Flesh Translucency (Average Score)	
	L	*a*	*b*	*L*	*a*	*b*	5DAS	15 DAS
T1: Chitosan 1%	70.04	18.06	41.82	61.53	-1.87	16.62	1.00	1.25
T2: Chitosan 2%	45.72	37.68	38.61	53.22	1.81	34.10	1.50	1.75
T3: Lemon Grass Oil 0.5%	49.53	10.93	6.65	58.99	-1.83	28.58	1.00	1.25
T4: Basil Oil 0.5%	41.52	20.52	30.59	51.91	1.17	36.08	1.50	1.75
T5: Chitosan 1%+ Lemon Grass Oil 0.5%	28.09	0.01	7.98	67.21	-1.78	15.80	1.00	1.00
T6: Chitosan 1% + Basil Oil 0.5%	39.06	41.20	41.89	45.39	-2.88	33.58	1.25	1.50
T7: Chitosan 2%+ Lemon Grass Oil 0.5%	58.39	40.29	37.46	55.77	-2.27	26.46	1.25	1.50
T8: Chitosan 2% + Basil Oil 0.5%	26.87	22.72	30.09	51.87	-0.61	31.75	1.50	2.00
T9: Control	32.10	28.39	31.80	52.46	1.99	33.16	1.75	2.50
SEm±	-	-	-	-	-	-	-	-
CD at 5%	-	-	-	-	-	-	-	-

Flesh translucency

Fruits of control showed the highest flesh translucency score 2.50 at 15 DAS whereas the lowest flesh translucency score was recorded in T5 (chitosan 1% + lemon grass oil 0.5%) with 1.00 (100% opaque) at 15 DAS (Table 2). The electrolyte leakage in the fruit flesh tissue causes the flesh translucency (Chen and Paul, 2001). Surface coating of pineapple fruit was reported to be free from flesh translucency at storage (Othman, 2008).

Total Soluble Solids (TSS)

The total soluble solid (TSS) content of pineapple was found highest (16.25ºBrix) in control whereas, it was found lowest (12.55ºBrix) at T5 (Chitosan 1%+ Lemon Grass Oil (0.5%) at 5 DAS. After 15 days of ambient storage, fruits at T5(Chitosan 1%+ Lemon Grass Oil (0.5%) had maximum TSS content (15.25ºBrix) compared with control (12.15ºBrix)(Table 4). The lower TSS in fruit is the result of slow hydrolysis of carbohydrates to sugars, due to decrease respiration rate that slow down the synthesis and use of metabolites (Yaman and Bayoindirli, 2002). However, at later stage, the drop in TSS marked the senescence of the stored fruit.

Titratable acidity and TSS:Acid ratio

Titratable acidity of stored pineapple fruit was found minimum on fruits treated with Chitosan 1% + Lemon grass oil (0.5%) at 5 DAS (0.55%) and 15 DAS (0.62%). On the contrary, sample at control showed maximum titratable acidity at 5 DAS (0.87%) and 15 DAS (1.04%) (Table 4). Maximum TSS:acid ratio was observed in fruits at T5 (Chitosan 1%+ Lemon Grass Oil 0.5%) was 22.82 and 24.60 at 5 and 15 DAS respectively (Table 4). The lowest ratio was recorded in control with 18.68 and 11.68 at 5 and 15 DAS, respectively. The decreasing acidity at the end of storage might be due to the metabolic changes in fruits or due to the use of organic acid in respiratory process that is compatible with other scientists (Ibrahim et al., 2014). Ali et al. (2015) reported the treatment combination of essential oil and chitosan maintained higher titratable acidity as compared to control.

Table 4: Effect of postharvest treatments on TSS, Titratable acidity and TSS:acid ratio

Treatments	TSS (^{0}Brix)		Titratable acidity (%)		TSS:acid Ratio	
	5DAS	15 DAS	5DAS	15 DAS	5DAS	15 DAS
T1: Chitosan 1%	12.85	14.45	0.61	0.72	21.07	20.07
T2: Chitosan 2%	14.15	12.85	0.75	0.89	18.87	14.44
T3: Lemon Grass Oil 0.5%	12.75	14.55	0.58	0.65	21.98	22.38
T4: Basil Oil 0.5%	13.85	14.05	0.69	0.85	20.07	16.53
T5: Chitosan 1%+ Lemon Grass Oil 0.5%	12.55	15.25	0.55	0.62	22.82	24.60
T6: Chitosan 1% + Basil Oil 0.5%	12.95	14.30	0.64	0.75	20.23	19.07
T7: Chitosan 2%+ Lemon Grass Oil 0.5%	13.25	14.20	0.67	0.79	19.78	17.97
T8: Chitosan 2% + Basil Oil 0.5%	14.65	13.55	0.71	0.82	20.63	16.52
T9: Control	16.25	12.15	0.87	1.04	18.68	11.68
SEm±	0.5827	0.5827	0.0540	0.0572	0.7753	0.6647
CD at 5%	0.8250	0.8250	0.0764	0.0810	1.0977	0.9410

Total sugar and reducing sugar

Fruits of control showed a gradual increase in total sugar content at 5 DAS (7.85%) and later decrease at 15 DAS (6.28%) (Table 5). At 15 DAS, maximum total sugar content (7.41%) was observed at T5 (Chitosan 1%+ Lemon Grass Oil (0.5%) followed by samples treated with T3 (lemon grass oil 0.5%) (7.23%) and T1 (Chitosan 1%) (7.18%). The reducing sugar content showed an increasing trend in all the treatments. However, the fruits at control showed decrease in reducing sugar content from 6.42% (at 5 DAS) to 5.02% (at15 DAS). Maximum reducing sugar (6.13%) was observed at T5 (Chitosan 1%+ Lemon Grass Oil (0.5%) followed by the fruits treated with Lemon Grass Oil at 0.5% (6.02%) at 15 DAS (Table 5). Ibrahim et al. (2014) reported that the gradual increase in reducing sugars in coated pineapple as compared to control treatment might be attributed due to the slow ripening process. Maximum amount of reducing sugars in treated fruits might be due to gradual conversion of starch to sugars, moisture loss and decrease in acidity by physiological changes during storage.

Ascorbic acid

The ascorbic acid content in fruits was tended to decline during storage. Among all the postharvest treatments, the fruits treated with T5 (Chitosan 1%+ Lemon Grass Oil 0.5%) recorded the highest ascorbic acid content at 5 and 15 DAS having 29.32 mg 100g-1 and 24.45 mg 100g-1 , respectively. The least ascorbic acid content was recorded in fruits at control having 17.36 mg 100g-1 and 11.75 mg 100g-1, respectively at 5 and 15 DAS (Table 5). The ascorbic acid content of pineapple gradually decreased with the increase in storage period. Chien et al. (2007b) reported that the coating of chitosan on fruits increase ascorbic acid content and reduce water lose in sliced mango fruit. It was reported by Petriccione et al. (2015 a, b) that the ascorbic acid loss was delayed in sweet cherry cultivar (*Prunus avium* L., namely cvs. "Ferrovia," "Lapins," "Della Recca") when treated with 0.5% chitosan coating, stored at 2 °C for 14 days.

Table 5: Effect of postharvest treatments on total sugar, reducing sugar and ascorbic acid

Treatments	Total Sugar (%)		Reducing Sugar (%)		Ascorbic Acid (mg $100g^{-1}$)	
	5DAS	15 DAS	5DAS	15 DAS	5DAS	15 DAS
T1: Chitosan 1%	4.92	7.18	3.26	5.94	24.82	21.05
T2: Chitosan 2%	5.92	6.46	4.32	5.46	21.08	17.47
T3: Lemon Grass Oil (0.5%)	4.87	7.23	3.14	6.02	26.58	22.18
T4: Basil Oil 0.5%	5.69	6.67	4.17	5.71	21.36	18.64
T5: Chitosan 1%+ Lemon Grass Oil 0.5%	4.72	7.41	2.94	6.13	29.32	24.54
T6: Chitosan 1% + Basil Oil 0.5%	5.18	6.92	3.85	5.87	24.61	19.72
T7: Chitosan 2%+ Lemon Grass Oil 0.5%	5.54	6.84	3.96	5.82	22.35	19.56
T8: Chitosan 2% + Basil Oil 0.5%	6.27	6.36	4.94	5.32	19.84	16.21
T9: Control	7.85	6.28	6.42	5.02	17.36	11.75
SEm±	0.4305	0.2310	0.2377	0.1881	0.6513	0.6744
CD at 5%	0.6095	0.3270	0.3365	0.2663	0.9221	0.9549

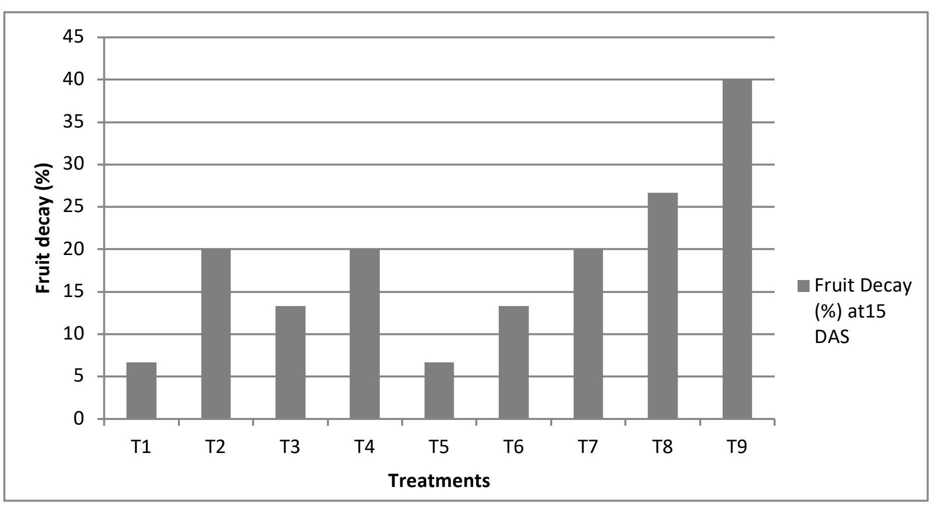

Fig. 1: Percent fruit decay of stored pineapple as influenced by selected postharvest treatments

Percentage of fruit decay and shelf life of fruit

Present study revealed that fruits treated with chitosan (1%) + Lemon grass oil (0.5%) had the minimum fruit decay (6.57 %) at 15 DAS (Fig. 1) as compared to control (40.00%) followed by the fruit treated with Chitosan (2%) + Basil oil (0.5%) (26.67%) and resulted in highest shelf life (19.93 days) (Fig. 2). Chien et al. (2007b) reported to have effectively controlling fruit decay while increasing the shelf life of citrus Murcott tangor by using chitosan. Murmu and Mishra (2018) found that edible coating with lemon grass oil, gum arabic and sodium caseinate had extended shelf life in guava.

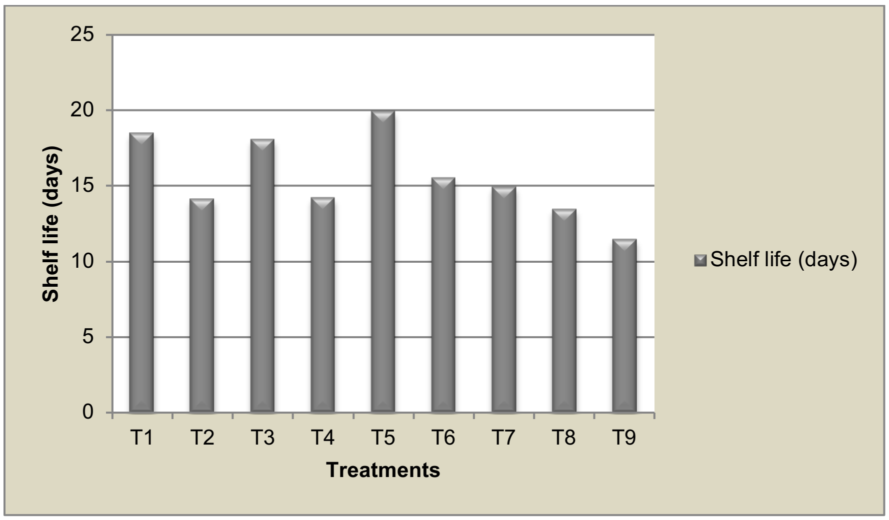

Fig. 2: Shelf life of stored pineapple as influenced by selected postharvest treatments

CONCLUSION

The present study revealed that pineapple fruits when coated with chitosan (1%) and lemon grass oil (0.5%) had minimum physiological weight loss, per cent decrease in length and fruit decay with good firmness of fruit. Besides, flesh translucency is low with high TSS, titratable acidity, total and reducing sugar and excellent shelf life. Therefore, the study recommends the developed coating formulation using chitosan (1%) + lemon grass oil (0.5%) to be a sustainable and efficient solution for maintaining quality, reducing postharvest losses and prolong shelf life of pineapples at ambient condition.

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