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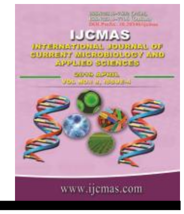

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Effect of Some Postharvest Treatments on Storage Quality of Apple cv. Royal Delicious under Ambient Storage

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Keywords

Apple, Postharvest treatments, 1-MCP, Starlight waxing, Leaf extracts, aCl2, Loss in weight, Fruit firmness, Total soluble solids, Reducing and total sugars, Titratable acidity, Pectin content, Starch-iodine rating, Respiration rate, Sensory evaluation, Spoilage

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ABSTRACT

All the treatments showed a beneficial effect on physical, biochemical and sensory parameter of fruits in comparison to control fruits. Among all treatments, 1250 ppb 1-MCP was proved to be the best in retaining the storage quality of fruits under ambient storage. After applying 1-Methylcyclopropene (1-MCP), *Aloe vera* leaf extracts alone and in combination with $CaCl_2$ and Starlight waxing treatments, fruits were stored under ambient conditions for 45 days, respectively. These treatments in general, slowed down the physiological changes and respiration rate of fruits, thereby proving to be effective in maintaining fruit quality during ambient storage. 1-MCP (1250 ppb) was the most effective treatment in this regard as the fruits retained maximum firmness, titratable acidity and exhibited lower decreases in physiological loss in weight, starch disappearance besides showing lower changes in TSS and sugar contents. Starlight waxing (75%) and *Aloe vera* leaf extracts, especially in combination with 1 per cent $CaCl_2$ were also quite effective in retaining quality of fruits in comparison to control fruits. These fruits also had higher sensory evaluation rating and hence the best overall acceptability ratings. However, *Aloe vera* whole leaf extract in combination with 1.0 per cent $CaCl_2$ efficiently reduced spoilage of fruit due to rots during storage.

Introduction

Apple, the premier table fruit of the world, belongs to the family Rosaceae and sub family Pomoideae. It is an important temperate fruit crop of the world with an annual production of 63.8 million metric tonnes from an area of 4.79 million hectares (FAO, 2008), with more than 80 per cent of the world's supply being produced in Europe (Asif, 2002). In India it is predominantly grown in the North-Western Himalayan region comprising of Jammu and Kashmir, Himachal Pradesh and Uttarakhand. Its cultivation has been extended to Arunachal Pradesh, Sikkim, Nagaland and Meghalaya in the North-Eastern region and Nilgiri hills in Tamil Nadu (Awasthi and Chauhan, 2002). Its attractive appearance, crispy flesh, pleasant flavour and sweet taste attract the consumers and fetch high price. It is an important source of vitamin C, vitamin A, thiamin and other vitamin complexes. About 1,739,000 metric tonnes of apples are reported to be produced in India annually (FAO, 2008).

Being a climacteric fruit, apple produces large amounts of ethylene during ripening as a result of which the fruit that reaches the consumers is usually in an over ripe stage. Such fruits also show marked losses in quality during storage. It is therefore necessary to reduce such losses by the use of simple technology which can be used by the growers right in their orchards. Such postharvest losses can be overcome by the use of appropriate postharvest treatments that have the potential to reduce spoilage and respiratory and transpirational losses by use of suitable chemicals, waxing material, natural extracts and storage conditions.

1-Methylcyclopropene (1-MCP) is an antagonist of ethylene action that binds to the ethylene receptor molecule in the tissues after treatment of fruits and delays ripening and the associated changes that are generally induced and accelerated by ethylene and it is being used extensively in horticulturally advanced countries. The application of plant nutrients like calcium (Ca) in the form of calcium chloride has also been reported to maintain cell integrity and firmness of fruits during storage. It is also believed to be involved as an anti-ripening and anti-senescence agent in fruit (Lester and Grusak, 1999; Betts and Bramlage, 1977), preventing cellular disorganization by maintaining protein and nucleic acid synthesis (Faust and Klein, 1974). Recently, there has been an increased interest in using *Aloe vera* gel as an edible coating material for fruits and vegetables driven by its antifungal activity (Martinez-Romero *et al.*, 2003; Saks *et al.*, 1995 and Rodriguez de Jasso *et al.*, 2005). In addition to the traditional role of edible coatings as a barrier to water loss and delaying fruit senescence, new generation coatings are being designed for incorporating and/or for controlled release of antioxidants, nutraceuticals, chemical additives and natural antimicrobial agents (Vargas *et al.*, 2008). Coating of fruits with wax emulsions immediately after harvest, act as a barrier to the diffusion of O_2 and CO_2 into and out of fruit, thereby reducing respiratory and transpirational processes.

Materials and Methods

Freshly harvested Royal Delicious apple fruits were procured from a well maintained commercial orchard in Devidhar village, Tehsil Rohru, Distt. Shimla (HP). Immediately after harvest fruits were properly packed in Corrugated Fibre Board (CFB) cartons with paper moulded trays and were promptly transported to the Postharvest Physiology Laboratory, Department of Food Science and Technology for conducting the studies. The research was conducted in the Department of Postharvest Technology, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) during the year 2010-11.

Details of treatments

After transportation of apple fruits to the Department of Food Science and Technology, the fruits were sorted and injured and blemished fruits were discarded. Fresh and uniform medium sized fruits were selected for the application of various postharvest treatments.

1-Methylcyclopropene (1-MCP) was applied as a fumigation treatment by placing the fruits in a closed tent with a calculated amount of chemical dissolved in water and a battery operated fan for 24 hours. Starlight wax manufactured by Pontes Industria de Cera Lida., Brazil was used for waxing of fruits. Wax solutions of different concentrations viz.

25, 50 and 75 per cent were prepared with water dilution in which fruits were dipped for 1 minute. Fruits were air dried in shade by spreading them on filter paper sheets under a fan at ambient condition.

Aqueous extracts of *Aloe vera* were prepared under laboratory condition on per cent basis as per the method described by Gakhukar (1996) and Sharma *et al.,* (1997). Aloe vera leaf extracts were prepared by grinding whole leaf, leaf peel and leaf gel separately in an electric blender. The aqueous extracts were diluted by adding appropriate quantity of distilled water to make up the desired concentration. Various concentrations of these treatments were applied to fruits as per details mentioned below.

TREATMENT NO.	TREATMENT DETAILS
T_1	1-MCP (750 ppb)
T_2	1-MCP (1000 ppb)
T_3	1-MCP (1250 ppb)
T_4	*Aloe vera* whole leaf extract
T_5	*Aloe vera* leaf peel extract
T_6	*Aloe vera* leaf gel extract
T_7	*Aloe vera* whole leaf extract + $CaCl_2$ (1%)
T_8	*Aloe vera* leaf peel extract + $CaCl_2$ (1%)
T_9	*Aloe vera* leaf gel extract + $CaCl_2$ (1%)
T_{10}	Waxing – Starlight (25%)
T_{11}	Waxing – Starlight (50%)
T_{12}	Waxing – Starlight (75%)
T_{13}	Control

Fruit storage and analysis

Fruits from all the treatments and replications were packed in CFB cartons for their storage under ambient conditions. Observations regarding physico-chemical characteristics of fruits were recorded at fortnightly intervals for fruits stored under ambient conditions. Physico-chemical analysis of fruits

Physical characteristics

Fruit weight/Physiological loss in weight (PLW)

At the start of the experiment marked fruits were weighed using a digital balance and the same fruits were weighed at an interval of 15 days under ambient conditions. The loss in weight at each interval during storage was expressed as percent of initial weight for every sample.

Fruit firmness

The fruit firmness was measured with a portable Effigi penetrometer (FT-327) which recorded the pressure required to force a plunger of 11 mm diameter into the flesh of pared fruit samples. The readings were taken on diagonally opposite sides of each fruit and results expressed in lbs/sq. inch.

Biochemical characteristics

Total soluble solids

The total soluble solid (TSS) contents in fruit juice were recorded with the help of an Erma hand refractometer. Few drops of juice were squeezed from the fruit on to the prism of the refractometer and readings were observed through the eye piece. For accurate measurement the readings taken were corrected for temperature variations to 20^0C and results expressed as ^{0}Brix (Ranganna, 1986).

Titratable acidity (TA)

A known weight of the fruit sample was crushed and taken in a 100 ml volumetric flask and the volume was made up by adding distilled water. After filtration, 10 ml of the filtrate was taken in a separate conical flask and titrated against 0.1 N sodium hydroxide using phenolphthalein as an indicator. The end point was determined by the appearance of a faint pink colour. Titratable acidity was calculated and expressed as per cent malic acid (Ranganna, 1986).

Reducing sugars

Reducing sugar contents were estimated by the Lane and Eynon's volumetric method (Ranganna, 1986). Samples were prepared by crushing weighed quantity of fruit, and making a known volume followed by titration against a known volume of Fehling's solutions using methylene blue as an indicator. The appearance of brick red precipitate was noted as the end point. The results are expressed as percent reducing sugar content.

Total sugars

The total sugar contents were also estimated by Lane and Eynon's volumetric method (Ranganna, 1986) by titrating the prepared sample, after hydrolysis with citric acid, against a known quantity of Fehling's solution using methylene blue as an indicator. The end point was attained when a brick red precipitate appeared in the solution. The results are expressed as percent total sugar.

Pectin content

Pectin content of the fruit was determined by Carre and Hayne's method as described by Ranganna (1986). The pectin extracted from the fruit was saponified with alkali and precipitated as calcium pectate from an acid solution by the addition of calcium chloride. The results are expressed as per cent calcium pectate.

Starch-iodine rating

The disappearance of starch in a section of fruit was evaluated by the 'starch-iodine test' as described by Phillips and Poapst (1959). The extent of the disappearance of starch in the fruits was categorized into nine stages by assigning numerical values from 1 to 9 to each of these stages. The starch content decreased as the numerical rating increased from 1 to 9.

Respiration rate

Respiration rate of fruits was analyzed with the help of O_2 and CO_2 analyzer (GFM 100 series, GAS Data Ltd.). At first, weight of fruit was recorded and the fruits were kept into a closed glass jar for an hour. The rate of respiration was recorded as ml CO_2/kg/hr.

Sensory evaluation

To assess consumer preference, sensory evaluation of experimental samples was conducted at different intervals of storage by a panel of judges, consisting of teachers, students and other staff members.

The panelists were given coded samples consisting of whole fruits and slices for giving their views on overall acceptability of the fruit. The evaluation was done by using the 9-point hedonic scale for each attribute (Wills *et al.*, 1980).

Fruit spoilage

Fruits spoiled due to fungal rots were counted at every storage interval and the total number was calculated by adding up all the diseased fruits from successive storage intervals. The spoilage percent was calculated by dividing the number of fruits spoiled by the total number of fruits stored and multiplying the result by 100.

Statistical analysis

The effect of various postharvest treatments of 1-Methylcyclopropene (1-MCP), *Aloe vera* leaf extracts, calcium chloride and waxing on fruit quality were assessed by Completely Randomized Design (CRD) whereas data pertaining to sensory evaluation was analyzed by randomized block design (RBD).

Results and Discussion

Physical characteristics

Physiological loss in weight (PLW)

Data pertaining to the effect of various postharvest treatments on physiological loss in weight (PLW) of apple fruits cv. Royal Delicious during ambient storage has been presented in the Table 1. The maximum mean PLW (6.36%) was recorded in control fruits which was significantly higher in comparison to all other treatments. Minimum mean PLW (5.0%) was recorded by application of 1250 ppb 1-MCP (T_3) and it was followed by waxing with 75 per cent Starlight (T_{12}) and 1000 ppb 1-MCP (T_2) respectively, although all these treatments were statistically at par. Treatments with extracts of different portions of *Aloe vera* leaf alone and in combination with $CaCl_2$ and lower concentration of Starlight wax were also effective in reducing PLW in comparison to controls. During storage an increase in PLW was observed with each successive sampling date under all treatments. The interaction between treatments and storage intervals was found to be significant. It was observed that all postharvest treatments were effective in decreasing physiological loss in weight (PLW) of fruits during ambient storage. The most effective treatment in this regard was fumigation with 1-Methylcyclopropene (1-MCP) though coating with Starlight wax and *Aloe vera* leaf extract, especially in combination with $CaCl_2$ were also quite effective. Physiological loss in weight of fruits during storage is believed to be due to losses of stored metabolites because of their utilization during respiration and loss of water. Water loss from fruits and vegetables is mainly due to transpiration although some of it may be lost by respiration and evaporation (Wilkinson, 1965). Moisture loss due to transpiration and evaporation is higher if the differences between surrounding and internal vapour pressure of the commodity is greater and such conditions can be seen when commodities are left unprotected. Conversely any coating material that creates an additional barrier to prevent moisture loss from the fruit surface can be expected to decrease moisture loss.

Fruit firmness

Data pertaining to the changes in fruit firmness of apple fruits cv. Royal Delicious as affected by various postharvest treatments during ambient storage is presented in the Table 2. From the data it is evident that there was a decrease in fruit firmness under all treatments as the storage period progressed. Among the various treatments tried 1250 ppb 1-MCP (T_3) was most effective in reducing the decrease and hence resulted in maximum mean firmness (12.45 lbs/sq. inch) of fruits which was significantly higher in comparison to all other treatments. *Aloe vera* leaf extracts, especially in combination with 1.0 per cent

$CaCl_2$, and Starlight waxing were also quite effective in retaining fruit firmness during storage. On the other hand minimum mean firmness was recorded in control which was significantly lower than all other treatments. 1-MCP has the potential to control ethylene action by blocking ethylene receptors (Sisler and Serek, 1997) thereby preventing or delaying changes associated with fruit ripening and hence maintaining fruit quality, mainly fruit firmness, not only during storage but also during the marketing and shelf-life periods (Streif, 2007).

Biochemical characteristics

Total soluble solids (TSS), Reducing sugars and Total sugars

Effects of various postharvest treatments on TSS content of apple fruits were recorded during ambient storage conditions and were expressed by the data presented in Table 3. The increase in TSS content of control fruits was observed only up to 15 days after which a faster decline was noticed resulting in the lowest TSS content by the last day of sampling; consequently resulting in the lowest mean value of 11.51^{o}Brix. Changes in TSS content as a result of other treatments were more gradual with Starlight waxing (T_{11} and T_{12}) and *Aloe vera* leaf extracts (T_6, T_4 and T_5) being more effective in retaining higher TSS levels although all the treatments, excepting T_3, were statistically at par. The minimum mean reducing sugars content (5.75%) was recorded in control fruits and it was significantly lower in comparison to all other treatments (Table 4). Among the other treatments fruit treated with 1-MCP in general had the lowest reducing sugar content. The maximum reducing sugar content (6.41%) was recorded in fruits treated with *Aloe vera* leaf peel extract (T_5) and it was followed by T_4, T_{10}, T_{12} and T_6, although all the treatments were statistically at par. The maximum mean total sugars content was recorded in fruits treated with *Aloe vera* leaf peel extract (T_5) and Starlight waxing treatments (T_{11} and T_{12}) where it was 8.44 per cent and these treatments were followed by T_4, T_{10}, T_6 and T_8, with all these treatments being statistically at par (Table 5). Minimum mean total sugars content was recorded in fruits treated with 1-MCP as it resulted in the most gradual changes in total sugars content although these fruits had comparably high total sugars content on the last sampling date. Total soluble solids (TSS), total sugars and reducing sugars contents of fruit in general, increased during the initial storage period and subsequently declined towards the end of storage in all treatments. The increase in TSS and sugar contents during storage may possibly be due to breakdown of complex organic metabolites into simple molecules or due to hydrolysis of starch into sugars, and on complete hydrolysis of starch no further increase in sugars occurred. Subsequently a decline in these parameters is evident as they along with other organic acids are the primary substrates for respiration (Wills *et al.,* 1980). The higher TSS and sugars content in control fruits during the initial sampling dates might be due to faster ripening changes resulting in breakdown of complex carbohydrates into simple sugars at a faster rate thereby increasing these constituents to the maximum extent and also due to the higher transpirational losses (Suni *et al.,* 2000) thereby having a concentration effect.

Titratable acidity (TA)

Data depicting the effect of various postharvest treatments on titratable acidity (TA) of apple fruits during ambient storage has been presented in Table 6. During storage, titratable acidity levels in fruits decreased significantly under all treatments, with the decrease being more rapid in control fruits which exhibited the lowest values for TA on each sampling date and also the lowest overall mean TA content. Therefore, maximum mean TA (0.27%) was recorded with the application of 1250 ppb 1-MCP (T_3) and it was followed by T_2 and then jointly by T_1, T_9 and T_{12}. The interaction between treatments and storage intervals was found to be significant. The decline was slowest in 1-MCP treated fruits, probably due to its ability to lower the rate of respiration, thereby delaying changes which are associated with ripening and senescence. However, the lowest mean titratable acidity was recorded in the control fruits, which can be ascribed to high metabolic activities resulting in utilization of organic acids as respiratory substrates during prolonged storage (Ulrich, 1974). Ball (1997) suggested that acidity decreases due to fermentation or break up of acids to sugars in fruits during respiration.

Pectin content

Data depicting the effect of various postharvest treatments on pectin content of apple fruits cv. Royal Delicious during ambient storage is presented in the Table 7. The maximum mean pectin content (1.31%) was recorded in fruits treated with *Aloe vera* leaf peel extract +1 per cent $CaCl_2$ (T_8) and it was followed by *Aloe vera* whole leaf extract + 1 per cent $CaCl_2$ (T_7) and then by 1250 ppb 1-MCP (T_3) and *Aloe vera* gel extract with $CaCl_2$ (T_9), respectively. The minimum pectin content was noticed in control fruits and it was significantly lower in comparison to all other treatments. The pectin content generally decreased with an increase in storage duration. The interaction between treatments and storage intervals was found to be significant. The degradation of pectin is controlled by the activity of pectic enzymes and their regulation by appropriate treatments may have beneficial effects in extending the storage life of fruits. The loss in pectin may be due to its break down during storage (Doesburg, 1957 and Sandhu *et al.*, 1990).

Starch-iodine rating

Data pertaining to the effect of various postharvest treatments on starch-iodine rating of apple fruits cv. Royal Delicious during ambient storage is presented in Table 8. From the data it is evident that minimum mean starch-iodine rating was recorded in T_3 (1250 ppb 1-MCP) and it was significantly lower than that in all other treatments and was followed by T_2, T_1 and T_{12}, respectively. Fruits treated with *Aloe vera* leaf extract also exhibited lower starch-iodine rating values in comparison to controls and the addition of $CaCl_2$ in these extracts caused a further decrease in starch iodine rating values. The starch-iodine rating values generally increased with an increase in storage duration under all the treatments. The interaction between treatments and storage intervals was found to be significant. Starch-iodine rating is an important parameter to determine the starch content in fruits. Highest rating was recorded in control fruits which might be due to the hydrolysis of starch into sugars during metabolic processes due to increase in respiration rate with the passage of storage period. Lowest rating was recorded in fruits treated with 1-MCP which might be due to its ability to reduce the rate of metabolism due to inhibition of ethylene action and the concomitant conversion of starch into sugars. Wills *et al.,* (1980) reported that with the advancement in storage period starch of apple get hydrolyzed and reaches to a level where it is undetectable by starch-iodine test.

Effect on respiration rate

Data pertaining to the effect of various postharvest treatments on rate of respiration of apple fruits cv. Royal Delicious during ambient storage is presented in the Table 9. 1-MCP treatments generally resulted in lowering the respiration rate on all sampling dates with its effect being proportional to the concentration applied. Hence, the minimum rate of respiration was recorded in fruits treated with 1250 ppb 1-MCP (T_3) which was significantly lower in comparison to all other treatments. Treatments with *Aloe vera* leaf extracts in general recorded higher respiration rates and the incorporation of 1 per cent $CaCl_2$ in the extracts of different leaf parts tended to reduce the respiration rate in comparison to extracts of respective leaf parts alone.

Table.1 Effect of postharvest treatments on changes in physiological loss in weight* (%) of apple fruits cv. Royal Delicious during ambient storage

Treatments (T)	Storage Interval in days (I)			
	15	30	45	Mean
T_1: 1-MCP (750 ppb)	4.65 (2.16)	5.10 (2.26)	5.58 (2.36)	5.11 (2.26)
T_2: 1-MCP (1000 ppb)	4.55 (2.13)	5.03 (2.24)	5.53 (2.35)	5.04 (2.24)
T_3: 1-MCP (1250 ppb)	4.53 (2.13)	4.99 (2.23)	5.50 (2.35)	5.00 (2.24)
T_4: *Aloe vera* whole leaf extract	5.52 (2.35)	5.90 (2.43)	6.34 (2.52)	5.92 (2.43)
T_5: *Aloe vera* leaf peel extract	5.62 (2.37)	6.11 (2.47)	6.62 (2.57)	6.12 (2.47)
T_6: *Aloe vera* leaf gel extract	5.50 (2.35)	5.68 (2.38)	6.10 (2.47)	5.76 (2.39)
T_7: *Aloe vera* whole leaf extract + $CaCl_2$ (1%)	5.04 (2.25)	5.50 (2.35)	6.06 (2.46)	5.53 (2.35)
T_8: *Aloe vera* leaf peel extract + $CaCl_2$ (1%)	5.46 (2.34)	5.91 (2.43)	6.35 (2.51)	5.91 (2.43)
T_9: *Aloe vera* leaf gel extract + $CaCl_2$ (1%)	4.92 (2.22)	5.35 (2.31)	5.89 (2.43)	5.38 (2.32)
T_{10}: Waxing-Starlight (25%)	4.70 (2.17)	5.18 (2.28)	5.65 (2.38)	5.18 (2.27)
T_{11}: Waxing-Starlight (50%)	4.48 (2.12)	5.10 (2.26)	5.72 (2.39)	5.10 (2.26)
T_{12}: Waxing-Starlight (75%)	4.40 (2.10)	5.06 (2.25)	5.57 (2.36)	5.01 (2.24)
T_{13}: Control	5. 70 (2.39)	6.40 (2.53)	6.98 (2.64)	6.36 (2.52)
Mean	5.01 (2.23)	5.48 (2.34)	5.99 (2.45)	
$CD_{0.05}$				
Treatments (T)	0.01			
Storage Interval (I)	NS			
T x I	0.02			

*Figures in parentheses are square root transformed values

Table.2 Effect of postharvest treatments on changes in fruit firmness (lbs/sq. inch) of apple fruits cv. Royal Delicious during ambient storage

Treatments (T)	Storage Interval in days (I)			
	15	30	45	Mean
T_1: 1-MCP (750 ppb)	14.27	12.40	9.62	12.10
T_2: 1-MCP (1000 ppb)	14.48	12.55	9.80	12.28
T_3: 1-MCP (1250 ppb)	14.62	12.78	9.96	12.46
T_4: *Aloe vera* whole leaf extract	13.90	11.32	8.72	11.32
T_5: *Aloe vera* leaf peel extract	13.58	10.90	8.48	10.99
T_6: *Aloe vera* leaf gel extract	14.10	11.68	8.86	11.55
T_7: *Aloe vera* whole leaf extract + $CaCl_2$ (1%)	14.42	12.50	9.65	12.19
T_8: *Aloe vera* leaf peel extract + $CaCl_2$ (1%)	14.25	12.36	9.58	12.06
T_9: *Aloe vera* leaf gel extract + $CaCl_2$ (1%)	14.58	12.72	9.72	12.34
T_{10}: Waxing-Starlight (25%)	13.96	11.38	8.85	11.40
T_{11}: Waxing-Starlight (50%)	14.08	11.46	8.99	11.51
T_{12}: Waxing-Starlight (75%)	14.20	11.62	9.05	11.63
T_{13}: Control	12.29	9.38	8.40	10.02
Mean	14.06	11.77	9.21	
Initial value: 17.5 lbs/sq. inch				
$CD_{0.05}$				
Treatments (T) 0.10				
Storage Interval (I) 0.05				
T x I 0.17				

Table.3 Effect of postharvest treatments on changes in total soluble solids (TSS) contents (ºBrix) of apple fruits cv. Royal Delicious during ambient storage

Treatments (T)	**Storage Interval in days (I)**			
	15	**30**	**45**	**Mean**
T_1: 1-MCP (750 ppb)	12.27	13.35	12.13	12.58
T_2: 1-MCP (1000 ppb)	12.13	13.03	12.55	12.57
T_3: 1-MCP (1250 ppb)	11.99	12.87	12.42	12.43
T_4: *Aloe vera* whole leaf extract	12.76	13.62	11.70	12.69
T_5: *Aloe vera* leaf peel extract	12.82	13.70	11.56	12.69
T_6: *Aloe vera* leaf gel extract	12.22	13.28	12.59	12.70
T_7: *Aloe vera* whole leaf extract + $CaCl_2$ (1%)	12.18	13.12	12.62	12.64
T_8: *Aloe vera* leaf peel extract + $CaCl_2$ (1%)	12.43	13.48	12.05	12.65
T_9: *Aloe vera* leaf gel extract + $CaCl_2$ (1%)	12.64	13.49	11.74	12.62
T_{10}: Waxing-Starlight (25%)	12.23	13.32	12.52	12.69
T_{11}: Waxing-Starlight (50%)	12.35	13.45	12.35	12.72
T_{12}: Waxing-Starlight (75%)	12.30	13.42	12.43	12.72
T_{13}: Control	13.42	12.84	8.28	11.51
Mean	12.40	13.40	12.30	
Initial value: 11.50ºBrix				
$CD_{0.05}$				
Treatments (T) 0.21				
Storage Interval (I) 0.10				
T x I 0.36				

Table.4 Effect of postharvest treatments on changes in reducing sugar content (%) of apple fruits cv. Royal Delicious during ambient storage

Treatments (T)	**Storage Interval in days (I)**			
	15	**30**	**45**	**Mean**
T_1: 1-MCP (750 ppb)	6.10	6.50	5.84	6.15
T_2: 1-MCP (1000 ppb)	6.02	6.42	5.79	6.08
T_3: 1-MCP (1250 ppb)	5.90	6.28	5.71	5.96
T_4: *Aloe vera* whole leaf extract	6.54	6.94	5.51	6.33
T_5: *Aloe vera* leaf peel extract	6.62	7.12	5.49	6.41
T_6: *Aloe vera* leaf gel extract	6.50	6.91	5.54	6.32
T_7: *Aloe vera* whole leaf extract + $CaCl_2$ (1%)	6.28	6.72	5.77	6.26
T_8: *Aloe vera* leaf peel extract + $CaCl_2$ (1%)	6.36	6.82	5.68	6.29
T_9: *Aloe vera* leaf gel extract + $CaCl_2$ (1%)	6.26	6.68	5.84	6.26
T_{10}: Waxing-Starlight (25%)	6.48	6.90	5.60	6.33
T_{11}: Waxing-Starlight (50%)	6.39	6.74	5.74	6.29
T_{12}: Waxing-Starlight (75%)	6.35	6.80	5.83	6.33
T_{13}: Control	7.24	6.52	3.48	5.75
Mean	6.38	6.80	5.68	
Initial value: 5.28%				
$CD_{0.05}$				
Treatments (T) 0.11				
Storage Interval (I) 0.05				
T x I 0.20				

Table.5 Effect of postharvest treatments on changes in total sugar content (%) of apple fruits cv. Royal Delicious during ambient storage

Treatments (T)	**Storage Interval in days (I)**			
	15	**30**	**45**	**Mean**
T_1: 1-MCP (750 ppb)	7.82	8.16	7.92	7.97
T_2: 1-MCP (1000 ppb)	7.76	8.08	7.84	7.89
T_3: 1-MCP (1250 ppb)	7.62	7.94	7.75	7.77
T_4: *Aloe vera* whole leaf extract	8.54	8.81	7.93	8.43
T_5: *Aloe vera* leaf peel extract	8.42	8.72	8.20	8.44
T_6: *Aloe vera* leaf gel extract	8.45	8.76	8.02	8.41
T_7: *Aloe vera* whole leaf extract + $CaCl_2$ (1%)	8.25	8.48	8.23	8.32
T_8: *Aloe vera* leaf peel extract + $CaCl_2$ (1%)	8.32	8.55	8.19	8.35
T_9: *Aloe vera* leaf gel extract + $CaCl_2$ (1%)	8.20	8.42	8.29	8.31
T_{10}: Waxing-Starlight (25%)	8.42	8.64	8.20	8.42
T_{11}: Waxing-Starlight (50%)	8.37	8.61	8.35	8.44
T_{12}: Waxing-Starlight (75%)	8.35	8.57	8.39	8.44
T_{13}: Control	9.28	8.24	6.85	8.12
Mean	8.24	8.50	8.13	
Initial value: 7.32%				
$CD_{0.05}$				
Treatments (T) 0.11				
Storage Interval (I) 0.05				
T x I 0.19				

Table.6 Effect of postharvest treatments on changes in titratable acidity content (as % malic acid) of apple fruits cv. Royal Delicious during ambient storage

Treatments (T)	**Storage Interval in days (I)**			
	15	**30**	**45**	**Mean**
T_1: 1-MCP (750 ppb)	0.27	0.23	0.19	0.23
T_2: 1-MCP (1000 ppb)	0.30	0.26	0.21	0.26
T_3: 1-MCP (1250 ppb)	0.32	0.28	0.22	0.27
T_4: *Aloe vera* whole leaf extract	0.23	0.18	0.15	0.19
T_5: *Aloe vera* leaf peel extract	0.20	0.16	0.12	0.16
T_6: *Aloe vera* leaf gel extract	0.26	0.20	0.16	0.21
T_7: *Aloe vera* whole leaf extract + $CaCl_2$ (1%)	0.30	0.26	0.20	0.25
T_8: *Aloe vera* leaf peel extract + $CaCl_2$ (1%)	0.25	0.20	0.17	0.21
T_9: *Aloe vera* leaf gel extract + $CaCl_2$ (1%)	0.28	0.22	0.19	0.23
T_{10}: Waxing-Starlight (25%)	0.21	0.18	0.14	0.17
T_{11}: Waxing-Starlight (50%)	0.24	0.21	0.17	0.20
T_{12}: Waxing-Starlight (75%)	0.27	0.22	0.19	0.23
T_{13}: Control	0.19	0.14	0.09	0.14
Mean	0.26	0.21	0.17	
Initial value: 0.39%				
$CD_{0.05}$				
Treatments (T) 0.05				
Storage Interval (I) 0.03				
T x I 0.09				

Table.7 Effect of postharvest treatments on changes in pectin content (as % calcium pectate) of apple fruits cv. Royal Delicious during ambient storage

Treatments (T)	**Storage Interval in days (I)**			
	15	**30**	**45**	**Mean**
T_1: 1-MCP (750 ppb)	1.39	1.23	0.90	1.17
T_2: 1-MCP (1000 ppb)	1.41	1.30	0.93	1.22
T_3: 1-MCP (1250 ppb)	1.43	1.31	0.99	1.24
T_4: *Aloe vera* whole leaf extract	1.35	1.24	0.94	1.18
T_5: *Aloe vera* leaf peel extract	1.27	1.05	0.63	0.98
T_6: *Aloe vera* leaf gel extract	1.40	1.28	0.98	1.22
T_7: *Aloe vera* whole leaf extract + $CaCl_2$ (1%)	1.45	1.34	1.02	1.27
T_8: *Aloe vera* leaf peel extract + $CaCl_2$ (1%)	1.48	1.38	1.08	1.31
T_9: *Aloe vera* leaf gel extract + $CaCl_2$ (1%)	1.40	1.33	1.00	1.24
T_{10}: Waxing-Starlight (25%)	1.37	1.21	0.67	1.08
T_{11}: Waxing-Starlight (50%)	1.40	1.28	0.73	1.13
T_{12}: Waxing-Starlight (75%)	1.42	1.30	0.78	1.17
T_{13}: Control	1.24	1.00	0.47	0.90
Mean	1.39	1.25	0.85	
Initial value: 1.96 %				
$CD_{0.05}$				
Treatments (T)	0.01			
Storage Interval (I)	0.02			
T x I	0.03			

Table.8 Effect of postharvest treatments on changes in starch–iodine rating of apple fruits cv. Royal Delicious during ambient storage

Treatments (T)	**Storage Interval in days (I)**			
	15	**30**	**45**	**Mean**
T_1: 1-MCP (750 ppb)	4.50	5.62	6.89	5.67
T_2: 1-MCP (1000 ppb)	4.40	5.52	6.88	5.60
T_3: 1-MCP (1250 ppb)	4.35	5.48	6.82	5.55
T_4: *Aloe vera* whole leaf extract	5.62	6.70	7.84	6.72
T_5: *Aloe vera* leaf peel extract	5.72	6.82	7.69	6.74
T_6: *Aloe vera* leaf gel extract	5.54	6.59	7.75	6.63
T_7: *Aloe vera* whole leaf extract + $CaCl_2$ (1%)	5.30	6.38	7.52	6.40
T_8: *Aloe vera* leaf peel extract + $CaCl_2$ (1%)	5.38	6.45	7.59	6.47
T_9: *Aloe vera* leaf gel extract + $CaCl_2$ (1%)	5.20	6.28	7.42	6.30
T_{10}: Waxing-Starlight (25%)	5.52	6.58	7.72	6.60
T_{11}: Waxing-Starlight (50%)	5.42	6.50	7.64	6.52
T_{12}: Waxing-Starlight (75%)	5.39	6.48	7.62	6.49
T_{13}: Control	5.75	6.90	8.05	6.90
Mean	5.24	6.33	7.49	
Initial value: 4.00				
$CD_{0.05}$				
Treatments (T) 0.02				
Storage Interval (I) 0.01				
T x I 0.03				

Table.9 Effect of postharvest treatments on changes in the rate of respiration (ml CO2/kg/hr) of apple fruits cv. Royal Delicious during ambient storage

Treatments (T)	**Storage Interval in days (I)**			
	15	**30**	**45**	**Mean**
T_1: 1-MCP (750 ppb)	16.51	19.32	17.85	17.90
T_2: 1-MCP (1000 ppb)	16.44	19.23	17.75	17.81
T_3: 1-MCP (1250 ppb)	16.41	19.21	17.71	17.77
T_4: *Aloe vera* whole leaf extract	19.29	25.65	22.59	22.51
T_5: *Aloe vera* leaf peel extract	19.33	25.72	22.69	22.58
T_6: *Aloe vera* leaf gel extract	19.26	25.64	22.58	22.50
T_7: *Aloe vera* whole leaf extract + $CaCl_2$ (1%)	19.21	25.56	22.49	22.42
T_8: *Aloe vera* leaf peel extract + $CaCl_2$ (1%)	19.26	25.59	22.51	22.45
T_9: *Aloe vera* leaf gel extract + $CaCl_2$ (1%)	19.19	25.52	22.42	22.38
T_{10}: Waxing-Starlight (25%)	17.12	21.46	19.47	19.35
T_{11}: Waxing-Starlight (50%)	16.98	21.38	19.35	19.24
T_{12}: Waxing-Starlight (75%)	16.88	21.29	19.25	19.14
T_{13}: Control	20.58	18.35	16.82	18.59
Mean	18.19	22.61	20.27	
Initial value: 15.35 ml CO_2/kg/hr				
$CD_{0.05}$				
Treatments (T) 0.03				
Storage Interval (I) 0.01				
T x I 0.05				

Table.10 Effect of postharvest treatments on overall acceptability rating (on 9-point hedonic scale) of apple fruits cv. Royal Delicious during ambient storage

Treatments (T)	**Storage Interval in days (I)**			
	15	**30**	**45**	**Mean**
T_1: 1-MCP (750 ppb)	7.76	6.74	5.78	6.76
T_2: 1-MCP (1000 ppb)	7.80	6.78	5.82	6.80
T_3: 1-MCP (1250 ppb)	7.84	6.82	5.85	6.84
T_4: *Aloe vera* whole leaf extract	7.22	6.20	5.23	6.22
T_5: *Aloe vera* leaf peel extract	7.20	6.18	5.15	6.18
T_6: *Aloe vera* leaf gel extract	7.23	6.22	5.21	6.22
T_7: *Aloe vera* whole leaf extract + $CaCl_2$ (1%)	7.30	6.28	5.30	6.29
T_8: *Aloe vera* leaf peel extract + $CaCl_2$ (1%)	7.26	6.26	5.25	6.26
T_9: *Aloe vera* leaf gel extract + $CaCl_2$ (1%)	7.32	6.32	5.30	6.30
T_{10}: Waxing-Starlight (25%)	7.44	6.42	5.41	6.43
T_{11}: Waxing-Starlight (50%)	7.48	6.46	5.46	6.47
T_{12}: Waxing-Starlight (75%)	7.54	6.51	5.51	6.52
T_{13}: Control	7.12	6.05	5.12	6.10
Mean	7.43	6.40	5.42	
Initial value: 8.50				
$CD_{0.05}$				
Treatments (T)	0.06			
Storage Interval (I)	0.03			
T x I	0.10			

Table.11 Effect of some post-harvest treatments on spoilage* (%) of apple fruits cv. Royal Delicious apples during ambient storage

Treatments (T)	Storage Interval in days (I)			
	15	30	45	Mean
T_1: 1-MCP (750 ppb)	0.00 (0.71)	2.24 (1.65)	4.32 (2.20)	2.18 (1.52)
T_2: 1-MCP (1000 ppb)	0.00 (0.71)	2.11 (1.62)	3.91 (2.10)	2.01 (1.47)
T_3: 1-MCP (1250 ppb)	0.00 (0.71)	1.98 (1.58)	3.72 (2.06)	1.90 (1.45)
T_4: *Aloe vera* whole leaf extract	0.00 (0.71)	2.26 (1.66)	3.80 (2.07)	2.02 (1.48)
T_5: *Aloe vera* leaf peel extract	0.00 (0.71)	2.42 (1.71)	4.08 (2.14)	2.16 (1.52)
T_6: *Aloe vera* leaf gel extract	0.00 (0.71)	2.38 (1.70	3.96 (2.11)	2.11 (1.51)
T_7: *Aloe vera* whole leaf extract + $CaCl_2$ (1%)	0.00 (0.71)	1.10 (1.26)	2.24 (1.66)	1.11 (1.21)
T_8: *Aloe vera* leaf peel extract + $CaCl_2$ (1%)	0.00 (0.71)	1.98 (1.58)	3.25 (1.94)	1.74 (1.41)
T_9: *Aloe vera* leaf gel extract + $CaCl_2$ (1%)	0.00 (0.71)	1.22 (1.31)	2.92 (1.85)	1.38 (1.29)
T_{10}: Waxing-Starlight (25%)	0.00 (0.71)	2.32 (1.68)	4.41 (2.22)	2.24 (1.53)
T_{11}: Waxing-Starlight (50%)	0.00 (0.71)	2.19 (1.64)	3.99 (2.12)	2.06 (1.49)
T_{12}: Waxing-Starlight (75%)	0.00 (0.71)	2.02 (1.59)	3.78 (2.07)	1.93 (1.46)
T_{13}: Control	0.00 (0.71)	4.92 (2.33)	8.74 (3.04)	4.55 (2.03)
Mean	0.00 (0.71)	2.24 (1.64)	4.09 (2.12)	
$CD_{0.05}$				
Treatments (T) 0.01				
Storage Interval (I) 0.02				
T x I 0.04				

*Figures in parentheses are square root transformed values

On the other hand the control fruits exhibited a faster increase in the respiration rate upto 15 days during storage and the subsequent decrease in respiration of these fruits was also faster. The control fruits therefore had the lowest respiration rate on the 45th day of storage. Other treatments exhibited an increase in the respiration rate upto 30 days before declining gradually during subsequent storage. The interaction between treatments and storage intervals was found to be significant. Lower rate of respiration in fruits treated with 1-MCP in comparison to other treatments could be due to its ability to inactivate ethylene, thus reducing the respiration rate of apple fruits. 1-MCP is an ethylene action inhibitor acting at very low concentrations, which has been reported to delay ripening and enhance storage life in intact and fresh cut fruits (Antunes *et al.,* 2008).

Effect on sensory evaluation

Overall acceptability rating

Data in Table 10 represents the effect of various postharvest treatments on overall acceptability rating of apple fruits during ambient storage. A perusal of the data shows that the score for overall acceptability decreased during the entire 45 day storage period under all the treatments. The decrease was faster in control fruits which were ultimately rated to be the least acceptable. However, the treatment T_3 (1250 ppb 1-MCP fumigation) resulted in maximum mean acceptability rating of fruit (6.84) and it was followed by T_2, T_1 and T_{12}, respectively. Interactions between treatments and storage intervals were found to be significant. Sensory quality is a criteria for determining the acceptability of any food or food product by the consumers. Overall acceptability of food in addition to quality and nutritional attributes also depends on the sensory quality. Improvement in palatability rating of guava fruit with 1-MCP treatment has also been reported by Bassetto *et al.,* (2005) and Mahajan and Singh (2008).

Effect on fruit spoilage

Data presented in the Table 11 shows the extent of spoilage in apple fruits cv. Royal Delicious in response to different postharvest treatments. The minimum mean fruit spoilage (1.11%) was recorded with T_7 (*Aloe vera* whole leaf extract + 1.0 per cent $CaCl_2$) which was significantly lower in comparison to all other treatments and was followed by *Aloe vera* leaf gel extract + 1.0 per cent $CaCl_2$ (T_9) and 1250 ppb 1-MCP (T_3), respectively, although all other treatments also caused significant reductions in spoilage over the control fruits where maximum spoilage (4.55%) was recorded. During storage spoilage was not detected in any of the treatments upto 15 days which increased significantly to 2.24 and 4.09 per cent by the 30^{th} and 45^{th} day, respectively. Reductions in spoilage with botanical extracts have also been reported by Singh *et al.,* (2000) and Bhardwaj and Sen (2003) on mango and Nagpur mandarins, respectively. *Aloe vera* based coatings have been reported to prevent loss of moisture and firmness, control respiratory rate, maturation and reduce microorganism proliferation in fruits such as sweet cherry (Martinez-Romero *et al.,* 2006), table grapes (Valverdo *et al.,* 2005) and nectarines (Ahmed *et al.,* 2009).

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