J Food Sci Technol (March–April 2013) 50(2):325–331
DOI 10.1007/s13197-011-0322-3

ORIGINAL ARTICLE

Effect of pre-cooling, fruit coating and packaging on postharvest quality of apple

R. M. Nilanthi Anuruddika Wijewardane · S. P. S. Guleria

Revised: 21 January 2011 / Accepted: 5 February 2011 / Published online: 1 April 2011

Abstract Freshly harvested apple fruits cv.'Royal Delicious' were subjected to Surface coating with 1, 1.5, 2% neem oil (*Azadirachta indica*) and 10, 15, 20% marigold flower (*Tagetes erectus*) extracts with pre cooling on apple storage quality was tested. Then the fruits were analyzed for physicochemical and physiological characters such as loss in weight, fruit firmness, total soluble solids (TSS) content, titratable acidity (TA), pH, reducing sugar contents, pectin, total anthocyanin, polygalacturonase (PG) activity and fruit spoilage. The results revealed that, the 1.5–2% concentration of neem oil as a surface coating along with pre-cooling was the most effective by retaining better physiochemical characteristics, in addition, significantly lowering disease incidence. Similarly, packaging of fruits with corrugated fiber board (CFB) boxes + paper mould trays, CFB + Polyethylene (PE) liners and shrink wrapped tray packing during storage (18–25 °C and 65–75% RH), revealed that 2% neem oil surface coating with shrink wrap tray packing resulted the better retention of storage life and, whereas, the treatment effect on physico-chemical characteristics of fruits were significant ($p<0.05$). However, the treatment effect was statistically at par with the marigold extract application with shrink wrapped tray packing in pre cooled fruits (10–15 °C, 70–75% RH) during ambient storage (18–25 ° C, 65–75% RH).

Keywords Apple · Pre-cooling · Surface coatings · Neem oil · Marigold flower extracts · Storage

Apple (*Malus domestica)* is commercially cultivated in Jammu and Kashmir, Himachal Pradesh, Uttrakhand having 99% of the total production accounting for about 2.5% of world apple production. (Anon 2005). The production of fruit 2006–07 as per the data available with the National Horticulture Board (NHB) is 58.92 million tones and latest information indicates that 30% of all fruits produced (roughly worth Rs 13,600 cores) are lost due to mismanagement. In case of apple, the loss percentage was 10–25% from the total production (Anon 2007). Due to its tendency towards fast ripening and texture breakdown, apple is difficult to keep well for longer period of time. Number of workers has made attempts to enhance the storage life of apple using different substances at the pre or postharvest stages. However, most of the synthetic chemicals being used for crop protection are reported to pose a serious threat to human health and have residual effect, beside being costly, therefore, all these factors have led to research for safer and more competitive alternatives. However, it has been reported that various botanical extracts such as neem leaf extracts, neem kernel oil, *Malia* leaf extracts, *Mentha* leaf extracts, onion extracts are residue free and safe from consumption point of view as compared to fungicides that are highly toxic to living beings. These extracts have a number of active ingredients that help in checking decay losses in fruits that are caused by the fungal infection (Bhowmick and Choudhary 1992). Kleeberg (1996); Deshmukh et al (1992) have reported that azadirachtin, camacin, menthol and euglone were the active compounds in neem, melia, mentha and walnut leaves, respectively; and that these substances strengthened the pectin molecule by

R. M. N. A. Wijewardane (✉)
Institute of Post- harvest Technology,
Jayanthi Mawatha,
Anuradhapura, Sri Lanka
e-mail: nilanthiwijewardana@yahoo.com

S. P. S. Guleria
Department of Post-harvest Technology,
Dr Y S Parmar University of Horticulture and Forestry,
Nauni, Solan 173 230, India

eliminating the chances of methyl group removal from the alpha-galactouronic acid residue of pectin; and therefore, helped in lowering the breakdown of pectin during storage. The distinguishing feature of the *Tagetes* genus is the presence of conspicuous brown black glands, which contain highly odoriferous components (Rodriguez and Mabery 1977).Various *Tagetus* oils analyzed by GC-MS were shown to contain limonene, tagetone, dihydrotagetone, ocimene, ocimenone and α-terpinoles (Vasudevan et al 1997); and, as such, who have further reported that the extracts from Tagetes, Mentha and Pelargonium were significantly effective in reducing stem end rot of pear (*Pyrus communis*); and that the test plant extracts provided better protection rather than eradicants.

Also, pre-cooling facilitates the good temperature management for prevention of ripening and that the on set of senescence is effectively delayed by maintaining low product temperature helps in reducing water loss and subsequent, product shriveling when combine its with packaging (Kaynas and Sivritepe 1995).

Therefore the present investigation was conducted to determine the effect of pre-cooling, in combination with the use natural extracts as fruit coating and different packages to enhance the storage quality of apple cv. 'Royal Delicious' under ambient storage.

Materials and methods

Royal Delicious apple fruits were procured from a well maintained commercial orchard situated at an elevation of 5,500 feet above meen sea level in village Chiathla (Kotkhai), District Shimla, Himachal Pradesh, India. The total number of fruits for this experiment was divided in to two sets. Before transportation one set was subjected to pre-cooling for 30 minutes at 10–15 °C, 70–75% RH in orchard itself by using low-pressure container which has been specially designed by modifying the head of an autoclave of 20 L capacity provided with a glass flat bottom flask designed as a humidifier. The pressure was maintained at 500 mmHg. The other set of fruit was not pre-cooled. Fruit from both the sets were subjected to postharvest treatments.

Preparation of solutions and treatment of fruits

The flower extract was prepared by drying of flowers under shade followed by grinding them to powder form in an electric blender. Aqueous solution was prepared by soaking a known weight of the powder material in an equal quantity of water and keeping it over night. The extract was separated with the help of muslin cloth and it was considered to be of 100 percent strength. It was diluted by adding appropriate quantity of distilled water to make up the desired concentrations. 2.0 % guar gum was added to make a coating solution. The solutions of neem oil was prepared by proper mixing of oil with distilled water emulsifying with guar gum on % weight basis (2 ml oil/ 100 ml of distilled water with 2 % guar gum). For the surface application of coating treatments, both the pre-cooled and non-pre-cooled fruits were used. After washing and air-drying, these fruits were subjected to different postharvest coating treatments with marigold extract and neem oil by dipping them for 5 minutes.

The pre-cooled as well as not pre-cooled fruits were dipped in 10,15, 20% marigold flower extract (T_1,T_2,T_3) and 1, 1.5, 2% of neem oil (T_4,T_5,T_6) for 5 minutes and control (T_7) was without any treatment. Then the fruits were packed in 3 types of packages; shrink wrapped tray packing (P_1), Paper mould tray + CFB carton (P_2), LDPE (150 gauge) liner + CFB carton (P_3).

Fruit storage

Fruits from all the treatments and replicates were stored at ambient (18–25 °C, 65–75% RH) storage and the observation with regard to the physiological and physico-chemical characteristics of fruits were recorded at an interval of 15 days for 45 days of storage.

Physical characteristics

Pre-weighed fruit samples were weighed on a top loading balance (OHAUS, model ARA 520, New Jersey, 07058, USA) after each storage interval. The losses in weight during storage were expressed as % of initial weight on each sample date. Fruit firmness was measured with Effigi Penetrometer with 11 mm probe tip (model FT 327,Effegi Alfonsine, Italy), which recorded the pressure required to force a plunger of 11 mm diameter into pared flesh of fruit samples.

Physico-chemical characteristics

The total soluble solids (TSS) content in fruit juice was recorded with the help of hand refractometer (ATAGO, model: HR-5[0–90%], Japan) by squeezing the juice with cotton wool on to the cleaned sensor and reading was reported as ºBrix. pH, of a known amount of fresh and homogenized fruit juice in a 100 ml beaker was recorded with a digital pH meter (Thermoorion, model 230A+, 9157 BN, Witchford, England) after standardizing the pH meter with buffer solutions of pH 4 and 7 (Ranganna 1986). Titratable acidity was determined as per Horwitz (1980) method. A known weight of fruit sample was crushed and taken in to 250 ml volumetric flask and the volume was made up. After filtration, 10 ml of filtrate was titrated against 0.1 N NaOH using phenolphthalein as indicator. The reducing sugar content was estimated by Lane and Eynon's volumetric method (Horwitz 1980). Pectin content was determined by Carre and Hayne's methods as described by Ranganna (1986) and expressed as percent calcium pectate. Polygalacturonase activity (PG) was determined by the method described by Mahadevan and Sridhar (1982). The enzyme action mixture consisted of enzyme extract (2 ml) which was prepared by crushing fruit flesh, 4 ml of sodium polypectate substrate (by dissolving 750 mg of the sodium polypectate in 100 ml of acetate buffer, pH 5.2, heated to 50–60 °C and placed in a blender for mixing) and 1 ml of acetate buffer. Using Ostwald-type viscometer the content was mixed by gently drawing air through the large arm of the viscometer and suction was applied through the small arm of the viscometer and initial efflux time of mixture was determined. After 16 hours, again the efflux time of the mixture was measured. Anthocyanin pigments of apple fruit skin were extracted with solvent mixture of acidic ethyl alcohol (Ranganna 1986) and the intensity of colour was measured through 535 nm wavelength in a spectrophotometer against blank. Spoilage of fruits due to fungal rots was calculated by adding up the number of fruits spoiled on successive storage interval and calculating their percentage on the basis of number of fruits stored initially.

Statistical analysis

The experiments were carried out as completely randomized design (CRD) with three replicates. Each replicate consisted 25 fruits and 5 fruits from each replicate were used for analysis. Mean separation was done by Least Significant Different (LSD) (at α=0.05).

Results and discussion

Progressive and significant increase in physiological weight loss of fruits occurred in each treatments and pre-cooled fruits exhibited relatively slower loss in weight on the corresponding dates as compared to the non-pre-cooled (Table 1).This may be due to the fact that loss of moisture from pre-cooled commodities is slower if higher relative humidity is maintained in the storage atmosphere. Such conditions can easily be achieved by lowering the temperature as the storage environment tends to be more saturated simply by reduction in temperature (Lurie and Ben 1990).The results revealed that coating of fruits with 2 % neem oil (T_6) and 1.5 % neem oil (T_5) with shrink wrap tray packing had the minimum physiological weight loss (2.4–2.5%), possibly due to reduction of both the rate of metabolism and also prevents water loss (Bhardwaj and Sen 2003).

The decline in fruit firmness (Table 2) was significantly lower in pre-cooled fruits whereas, 2 % neem oil (T_6) coupled with shrink wrap tray packing was the most effective treatment in retaining fruit firmness (66.4 N) with

Table 1 Effect of pre cooling, fruit coating and packaging on the physiological weight loss (%) of Royal delicious apples during storage at 18–25 °C for 45 days

T						
	C_1			C_2		
P	P_1	P_2	P_3	P_1	P_2	P_3
T_1	4.7	5.4	5.8	4.7	5.7	6.0
T_2	5.0	5.3	5.7	4.4	5.5	5.9
T_3	3.1	4.3	4.7	3.0	4.0	4.7
T_4	4.4	4.7	5.2	3.7	4.9	5.4
T_5	2.5	3.5	4.1	2.2	3.4	4.0
T_6	2.4	3.8	3.8	2.0	3.6	3.8
T_7	5.5	5.9	6.2	5.5	6.3	6.5

$CD_{0.05}$ C=0.002, CxPxT =0.008

T treatments; *C_1* pre-cooled; *C_2* without pre cooled; (*P_1*) shrink wrapped tray packing; (*P_2*) Paper mould tray + CFB carton; (*P_3*) LDPE (150 gauge) liner + CFB carton; marigold flower extract:T_1–10%, T_2–15%, T_3–20% ;neem oil: T_4–1%, T_5–1.5%, T_6–2%, T_7– control. ($p<0.05$), $n=3$

Table 2 Effect of pre cooling, fruit coating and packaging on the fruit firmness (N) of Royal delicious apples during storage at 18–25 °C for 45 days

T						
	C_1			C_2		
P	P_1	P_2	P_3	P_1	P_2	P_3
T_1	55.3	49.5	51.7	52.4	45.1	47.2
T_2	61.6	51.0	55.6	57.4	51.7	54.5
T_3	64.2	62.8	62.4	60.4	56.5	57.7
T_4	64.6	59.6	63.8	61.0	56.9	56.8
T_5	65.0	61.4	62.9	60.9	57.4	59.2
T_6	66.4	60.7	66.1	61.9	58.5	61.1
T_7	47.8	39.5	42.0	44.0	35.8	39.1

Initial value 76.21

$CD_{0.05}$ C=0.01, CxPxT =0.02

T treatments; *C_1* pre-cooled; *C_2* without pre cooled; (*P_1*) shrink wrapped tray packing; (*P_2*) Paper mould tray + CFB carton; (*P_3*) LDPE (150 gauge) liner + CFB carton; marigold flower extract:T_1–10%, T_2–15%, T_3–20% ;neem oil: T_4–1%, T_5–1.5%, T_6–2%, T_7– control. ($p<0.05$), $n=3$

respect to pre-cooled fruits. However, the possibility of achieving a modified atmosphere condition has been put forward as one of the advantages to be gained by the use of plastic films. This technique leads to reduction of metabolic rates, and prevention of water loss, which is further facilitated by the reduction in temperature (Singh and Chauhan 1986). Similar observations were recorded by Anzueto and Rizvi (1985), wherein at 21 °C heat shrinkable polymer packed apple fruits reached maximum acceptable conditions at 6 week of storage against the shelf life extension of 3–4 weeks over non-packed controls.

Pre-cooled fruits retained maximum TA content whereas, minimum fruit juice pH (4.0) was recorded with respect to pre-cooled fruits packed in shrink wrapped tray package, with treatment T_5 and T_6 (Table 3). The lower level of titratable acidity content and higher pH was recorded by control (T_7). The faster rate of decline in acidity in control fruits could be due to the faster metabolic reactions occurring within them. The application of different coating treatments may also slow down the metabolism of fruits as these have been reported to maintain higher CO_2 and lower O_2 levels inside the coated fruits (Kader et al 1989), and this might explain the retention of higher acid levels and, consequently, lower pH values . Among the metabolic reactions, respiration is an important process, which may utilize organic acids as a substrate during the peak energy requirement of fruits, which usually coincides with ripening leading to a decrease in pH during prolonged storage (Sonkar and Ladaniya 1999).

Maximum TSS content 16.2°B was recorded in response to coating with 1.5% neem oil with pre-cooled fruits whereas, the maximum reducing sugar contents,

Table 3 Effect of pre cooling, fruit coating and packaging on the titratable acidity (% malic acid) and pH of Royal delicious apples during storage at 18–25 °C for 45 days

Titratable acidity (% malic acid)						
T						
	(C_1)			(C_2)		
(P)	P_1	P_2	P_3	P_1	P_2	P_3
T_1	0.3	0.2	0.2	0.2	0.2	0.2
T_2	0.3	0.2	0.3	0.3	0.2	0.2
T_3	0.3	0.2	0.3	0.3	0.2	0.2
T_4	0.3	0.3	0.3	0.3	0.2	0.2
T_5	0.3	0.3	0.3	0.3	0.2	0.3
T_6	0.3	0.3	0.3	0.3	0.3	0.3
T_7	0.2	0.2	0.2	0.2	0.2	0.2
Initial value: 0.39						
$CD_{0.05}$ C=0.01, CxPxT=0.02						
pH						
T_1	4.4	4.5	4.2	4.5	4.6	4.6
T_2	4.3	4.5	4.5	4.5	4.6	4.6
T_3	4.1	4.3	4.2	4.3	4.4	4.4
T_4	4.3	4.4	4.3	4.6	4.6	4.6
T_5	4.0	4.1	4.2	4.2	4.2	4.4
T_6	4.0	4.3	4.3	4.2	4.5	4.2
T_7	4.6	4.8	4.7	4.8	4.8	4.5

Initial value 3.3

$CD_{0.05}$ C=0.01, CxPxT=0.05

T treatments; *C_1* pre-cooled; *C_2* without pre cooled; (*P_1*) shrink wrapped tray packing, (*P_2*) Paper mould tray + CFB carton; (*P_3*) LDPE (150 gauge) liner + CFB carton ; marigold flower extract:T_1–10%, T_2–15%, T_3–20% ;neem oil: T_4–1%, T_5–1.5%, T_6–2%, T_7– control. ($p<0.05$), $n=3$

Table 4 Effect of pre cooling, fruit coating and packaging on the total soluble solids(B°) and Reducing sugar content (%) of Royal delicious apples during storage at 18–25 °C for 45 days

Total soluble solids(B°)						
T						
	(C_1)			(C_2)		
(P)	P_1	P_2	P_3	P_1	P_2	P_3
T_1	14.2	13.8	13.9	13.8	13.8	14.0
T_2	14.9	14.6	14.8	14.7	14.5	14.5
T_3	15.1	14.9	15.2	14.9	14.6	14.6
T_4	15.9	15.4	15.7	15.8	15.1	15.7
T_5	16.2	15.9	15.9	15.7	15.5	17.1
T_6	16.1	15.2	16.1	16.2	15.2	15.8
T_7	13.8	13.3	13.8	13.7	12.9	13.5
Initial value: 10.24						
$CD_{0.05}$ C=0.01 CxPxT=0.02						
Reducing sugar content (%)						
T_1	7.3	7.0	7.1	7.4	7.0	7.2
T_2	8.2	7.9	7.9	8.1	7.8	7.8
T_3	8.3	8.0	8.1	8.3	7.8	8.1
T_4	8.1	7.8	7.9	7.9	7.6	7.7
T_5	8.5	8.2	8.4	8.2	7.9	8.2
T_6	8.4	8.1	8.3	8.3	8.0	8.2
T_7	7.1	6.9	7.1	7.1	6.8	6.9

Initial value 5.54

$CD_{0.05}$ C=0.01, CxPxT=0.02

T treatments; *C_1* pre-cooled; *C_2* without pre cooled; (*P_1*) shrink wrapped tray packing, (*P_2*) Paper mould tray + CFB carton; (*P_3*) LDPE (150 gauge) liner + CFB carton ; marigold flower extract:T_1–10%, T_2–15%, T_3–20% ;neem oil: T_4–1%, T_5–1.5%, T_6–2%, T_7– control. ($p<0.05$), $n=3$

(8.4–8.5%) was recorded in (1.5–2.0%) neem oil treatments, when the fruits packed in shrink-wrap tray package and the minimum TSS content was recorded by control (Table 4). The increase in TSS and sugar content may be due to the hydrolysis of insoluble polysaccharides into simple sugars. The increase in TSS and sugar contents in control fruits may be due to the higher physiological weight loss in these fruits; and, as a result of which, there might have been an increase in the concentration of sugars and total soluble solids. At the same time, such changes are expected to be slower and more gradual when the metabolism of the commodity is slowed down by the application of treatments so adopted under experimentation coupled with precooling. So, with the decrease in metabolism, the rate of utilization of stored metabolites is also slowed down; and, thereby, resulting in retention of higher levels of these constituents. These findings are further supported by the observations of Singh and Mohammed (1997).

2% neem oil showed the higher value of total anthocyanin content (18.5 mg/100 g with shrink wrap tray packing with pre cooling. A continuous decrease in total anthocyanin content observed in all the treatments, whereas precooling, coating and shrink wrapped tray packing was effective for reduction in losses of pigment and this may possibly be due to the delayed senescence of tissues which involve the degradation of these pigments (Table 5).

The pectin content, in general, declined in all treatments. However, (1.5–2.0%) neem oil treatment (T_6) retained maximum pectin content, (1.3%), (Table 6). The decrease in pectin content in all treatments at the end of storage might be the result of pectolytic enzymes activity on natural pectin in the fruits (Nara et al 2001). According to present findings, neem oil exhibited better retention of PG over different concentration of marigold flower extracts, as well as the pre-cooling and packaging also showed a marked effect on reduction of fruit softening during storage. Gupta and Bhandari (1974) examine the composition and physio-chemical properties of *Tagatus erecta* flowering tops and reported the precence of d-limonene, ocemene, d-linalool, α-d-phellandrene, tagetone. Baslas and Singh (1980) reported the presence of α-pinene, β- pinene, dipentene, menthol and geraniol which having anti-repellent activity. Similar findings were reported by various workers with regard to effect of plant

Table 5 Effect of pre cooling, fruit coating and packaging on the total anthocyanin content (mg/100 g) of Royal delicious apples during storage at 18–25 °C for 45 days

T						
	C_1			C_2		
P	P_1	P_2	P_3	P_1	P_2	P_3
T_1	14.6	14.1	14.3	14.1	13.2	13.2
T_2	15.2	14.3	14.2	14.6	13.8	13.1
T_3	16.7	15.4	16.2	16.2	14.7	15.4
T_4	18.2	16.5	17.3	17.4	15.4	16.3
T_5	18.2	18.1	17.6	17.5	17.1	16.7
T_6	18.5	16.6	18.3	17.9	16.3	17.5
T_7	13.0	13.3	13.5	12.5	12.3	12.6

Initial value 30.4

$CD_{0.05}$ C=0.02, CxPxT=0.11

T treatments; C_1 pre-cooled; C_2 without pre cooled; (P_1) shrink wrapped tray packing; (P_2) Paper mould tray + CFB carton; (P_3)-LDPE (150 gauge) liner + CFB carton ; marigold flower extract:T_1–10%, T_2–15%, T_3–20% ;neem oil: T_4–1%, T_5–1.5%, T_6–2%,T_7– control. ($p<0.05$), $n=3$

Table 6 Effect of pre cooling, fruit coating and packaging on the pectin content and polygalacturonase (PG) activity of Royal delicious apples during storage at 18-25 °C for 45 days

Pectin content (% calcium pectate)						
T						
	C_1			C_2		
P	P_1	P_2	P_3	P_1	P_2	P_3
T_1	0.7	0.7	0.7	0.7	0.6	0.7
T_2	1.0	0.9	1.0	1.0	0.9	0.9
T_3	1.2	1.1	1.1	1.2	1.1	1.1
T_4	1.2	1.2	1.2	1.2	1.1	1.1
T_5	1.3	1.2	1.2	1.3	1.2	1.2
T_6	1.3	1.3	1.3	1.3	1.3	1.3
T_7	0.7	0.6	0.7	0.7	0.6	0.6
Initial value 1.98						
$CD_{0.05}$ C=0.01 CxPxT=0.03						
Polygalacturonase (PG) activity (% loss of viscosity)						
T_1	14.4	14.3	14.4	14.4	14.4	14.3
T_2	14.5	14.3	14.3	14.5	14.2	14.3
T_3	14.6	14.2	14.5	14.5	14.2	14.5
T_4	14.5	14.4	14.5	14.5	14.3	14.5
T_5	14.7	14.7	14.7	14.7	14.7	14.6
T_6	14.7	14.7	14.7	14.7	14.7	14.7
T_7	14.2	14.0	14.1	14.2	13.9	14.1
Mean C	14.4			14.4		

Initial value 10.04

$CD_{0.05}$ C=0.01, CxPxT=0.03

T treatments; C_1 pre-cooled; C_2 without pre cooled; (P_1) shrink wrapped tray packing; (P_2) Paper mould tray + CFB carton; (P_3) LDPE (150 gauge) liner + CFB carton ; marigold flower extract:T_1–10%, T_2–15%, T_3–20% ;neem oil: T_4–1%, T_5–1.5%, T_6–2%, T_7– control. ($p<0.05$), $n=3$

extracts in retention of enzymatic activity of fruits during storage (Singh et al 2000).

2 % neem oil treatment (T_6) was the most promising treatment to reduce fruit spoilage, as such, 1 % neem oil treatment (T_4), 1.5 % neem oil treatment (T_5) and 2 % neem oil treatment (T_6) were statistically at par with each other. Steinhauer (1987) is isolated a compound with antifungal activity from neem kernal extracts and has been used for control of phytopathogenic fungi such as *Penicillium expansum*. Neem oil and its isolates nimbidin, nimbidiol, and nimbin have been reported to inhibit fungal growth (Anon 1997).The antifungal effect of neem seed kernel extracts on the postharvest disease caused by *Penicillium expansum* isolated from the infected fruits under in vitro condition, results showed that the growth of pathogen can be significantly ($p<0.05$) reduced (Wang et al 2010). Spoilage of fruits due to rotting during storage reduced substantially by pre-cooling and coating treatments, whereas, neem oil 2 % combined with pre-cooling was found to be the most effective in reducing spoilage while control fruits exhibited maximum spoilage (Table 7). Gakhukar (1996) has given the most needed scientific explanation to the beneficial effects of plant extracts as he rightly opined that botanical extracts have the capability to act as antifeedent and anti-repellent and, thereby, inhibiting the pathogenicity of various organisms and helped in maintaining cellular integrity and lowering the disease incidence to such an extent that the sensorial characteristics improved (Ray et al 2000).

The effect of various postharvest coating treatments on overall acceptability rating (Table 8) of apple fruits held under ambient storage conditions narrated that the average score for overall acceptability decreased during storage; and the decrease being faster in control fruits (T_7) and, however, the fruits treated with 15 per cent marigold flower extract (T_2) and 1.5 per cent neem oil had a maximum overall acceptability score (7.5) with shrink wrap tray packing. Similar observations were recorded by Rajkumar et al. (2006) when using wax emulsion for guava fruits.

Table 7 Effect of pre cooling, fruit coating and packaging on the fruit spoilage (%) of Royal delicious apples during storage at 18–25 °C for 45 days

T						
	C_1			C_2		
P	P_1	P_2	P_3	P_1	P_2	P_3
T_1	3.4	4.5	3.8	6.0	5.1	4.4
T_2	2.6	3.5	2.7	4.0	4.7	4.5
T_3	1.6	2.7	2.2	2.6	3.6	3.2
T_4	1.2	1.3	1.4	1.5	2.3	1.6
T_5	0.8	0.7	0.5	0.8	0.9	0.9
T_6	0.7	0.8	0.7	0.8	0.9	0.8
T_7	5.0	5.4	5.0	5.9	6.0	5.5

$CD_{0.05}$ C=0.03, CxPxT=0.14

T treatments; *C_1* pre-cooled; *C_2* without pre cooled; (*P_1*) shrink wrapped tray packing; (*P_2*) Paper mould tray + CFB carton; (*P_3*) LDPE (150 gauge) liner + CFB carton ; marigold flower extract:T_1–10%, T_2–15%, T_3–20% ;neem oil: T_4–1%, T_5–1.5%, T_6–2%, T_7– control. ($p<0.05$), $n=3$

Table 8 Effect of pre cooling, fruit coating and packaging on the overall acceptability (rating on the basis of 9 point hedonic scale) of Royal delicious apples during storage at 18–25 °C for 45 days

T						
	C_1			C_2		
P	P_1	P_2	P_3	P_1	P_2	P_3
T_1	7.0	5.5	4.7	6.9	5.4	4.6
T_2	7.5	6.6	5.6	7.5	6.6	5.6
T_3	7.2	6.0	7.3	7.2	6.0	7.3
T_4	7.3	6.4	5.4	7.2	6.4	5.4
T_5	7.5	6.5	5.6	7.5	6.4	5.5
T_6	7.4	6.4	5.5	7.4	6.4	5.5
T_7	4.7	4.3	4.3	4.6	4.3	4.3

$CD_{0.05}$ C=0.01, CxPxT=0.14

T treatments; *C_1* pre-cooled; *C_2* without pre cooled; (*P_1*)-shrink wrapped tray packing; (*P_2*) Paper mould tray + CFB carton; (*P_3*) LDPE (150 gauge) liner + CFB carton ; marigold flower extract:T_1–10%, T_2–15%, T_3–20% ;neem oil: T_4–1%, T_5–1.5%, T_6–2%, T_7– control. ($p<0.05$), $n=3$

Conclusions

The results revealed that 1.5–2% concentration of neem oil as a surface coating along with pre-cooling at 10 °C was the most effective in providing better physico-chemical umbrella, significantly lowering the fruit spoilage. The neem oil surface coating along with shrink wrap tray packing under 18–25 °C (65–75% RH) resulted the longest storage life up to 45 days. Among three different concentrations of marigold flower extracts (10%, 15%, 20%), higher retention of fruit firmness, pectin content, anthocyanin pigments, PG enzyme activity was recorded by 20% marigold extract surface coating with shrink wrap tray packing along with pre cooling. Future research should be needed to encourage the use of such botanicals for development of edible wax formulations for other economically important fruits and to popularize among farmers.

Acknowledgement Author acknowledge Sri Lankan Council for Agricultural Research Policy, Institute of Post-harvest Technology and ICAR-CARP work plan to organize and sponsor study at Dr Y S Pamar University of Horticulture and Forestry, Nauni, Solan.

References

Anon (1997) Chemical Composition of Neem Tree. Neem Foundation. http://www.neemfoundation.org/comp.htm. (Accession date: 17.01.2011)

Anon (2005) Apple. http://www.fas.usda.gov/htp/horticulture/apple. (Accession date:17.11.2007)

Anon (2007) Annual Report (2006–07), Central Institute of Postharvest Engineering and Technology (CIPHET), Ludhiana

Anzueto CR, Rizvi SS (1985) Individual packaging of apples for shelf life extension. J Food Sci 50(2):897–900

Baslas RK, Singh AK (1980) Chromatographic separation of essential oil of *Tagetus erecta*. Indian Perfum 24(3):163–165

Bhardwaj RL, Sen NZ (2003) Zero energy cool chamber storage of Mandarin (*Citrus reticulate* cv. Nagpur Santra). J Food Sci Technol 40(6):669–672

Bhowmick BN, Choudhary BK (1992) Antifungal activity of leaf extracts of medicinal plant *Alternaria alternate*. Indian Bot Report 1(2):164–165

Deshmukh PB, Chavan SR, Rehapurkar DM (1992) A study of insecticidal activity of twenty indigenous plants. Pesticides 16 (12):7–10

Gakhukar RT (1996) Commercial and industrial aspects of neem based pesticide. Pestol 22(10):15–32

Gupta YS, Bhandari KS (1974) Chemical examination of essential oil from the flowering tops of *Tagetus erecta*. Indian Perfum 2:29–33

Horwitz W (1980) Official method of analysis, 13th edn. Association of Analytical Chemists, Washington DC

Kader AA, Zagory D, Kerbel EL (1989) Modified atmosphere packaging of fruits and vegetables. CRC Crit Rev Food Sci Nutr 28:1–30

Kaynas K, Sivritepe HO (1995) Effect of pre-cooling treatments on storage quality of mature green tomatoes. Acta Hortic 412:200–209

Kleeberg H (1996) The Neem Azal conception: Future possibilities of the use of neem in biological and integrated pest management. In: Singh RP, Chavi MS, Raheja RK, New Delhi (eds) Neem and environment. Oxford and IBH, New Delhi, pp 875–882

Lurie SK, Ben AR 1990.Physiological changes in diphenyl treated ‘Granny Smith’ apples. Israel J Bot 38(34): 199–207

Mahadevan A, Sridhar R (1982) Methods in physiological plant pathology. Sivakami Publ, Madras, pp 28–29

Nara K, Kato Y, Motomura Y (2001) Involvement of terminal arabinose and galactose pectic compounds in mealiness of apple fruit during storage. Postharvest Biol Technol 22(2):141–150

Rajkumar P, Kailappan R, Tirupathi V (2006) Studies on shelf life of fully ripe guava fruits using wax emulsion. Madras Agrcic J 93 (1–6):79–85

Ranganna S (1986) Hand book of analysis and quality control of fruit and vegetable products, 2nd edn. Tata McGraw Hill Pub Co, New Delhi, pp 12–99

Ray DP, Walia S, Dureja P, Singh RP (2000) Composition and repellent activity of essential oil of marigold (*Tagatus erecta* L.) flowers. Indian Perfum 44(4):267–270

Rodriguez E, Mabery TJ (1977) *Tagetea* Chemical Review. In: Heywood VH, Harborne JB, Turmer BL (eds) Biology and chemistry of the compositae, vol II. Academic, New York

Singh K, Chauhan KS (1986) Effect of certain postharvest treatments on storage life of cv. ‘L-49’ guava. Haryana J Hortic Sci 11(3–4):164–167

Singh UB, Mohammed S (1997) Comparative efficiency of wax emulsion and rice starch on postharvest shelf life of fully ripe guava fruits. J Food Sci Technol 34:519–522

Singh JN, Acharya P, Singh BB (2000) Effect of GA_3 and plant extracts on storage behaviour of mango (*Mangifera indica*) cv. Langra. Haryana J Hortic Sci 29:3–4

Sonkar RK, Ladaniya MS (1999) Individual film wrapping of Nagpur mandarin with heat stretching film for refrigerated storage. J Food Sci Technol 36:273–276

Steinhauer B (1987) Antifungal compounds from *Azadirachta indica*. In: Kleeberg H (ed) Practice oriented results on use and production of Neem ingredients and pheromones. Druck and Graphic, Giessen, pp 93–97

Vasudevan P, Tandon M, Pathak N, Nuennerich P (1997) Fluid CO_2 extraction and hydrodistillation of certain biocidal essential oils and their constituents. J Sci Ind Res 56:662–672

Wang J, Li J, Cao J, Jiang W (2010) Antifungal activities of Neem (*Azadirachta indica*) seed kernel extracts on postharvest diseases in fruits. Afr J Microbiol Res 7:591–595