Effect of near infrared reflection and evaporative cooling on quality of mangoes

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Abstract: Mango fruit is valuable in Kenya due to its nutritive and economic value. However, at least 40% to 45% of the fruit is lost during postharvest handling due to inadequate storage facilities. This study aimed at investigating the effect of combination of near infrared reflection (NIR) and evaporative cooling (EC) on quality of mangoes. Freshly mature Apple and Kent mangoes were selected, cleaned and stored in NIR store (S_{NR}). The shelf-lives and quality attributes namely physiological weight, colour and firmness were evaluated on daily basis against similar fruits stored in an equivalent non-NIR store (S_{NNR}). Storage under room conditions (R_C) was used as control experiment. Digital scale, Minolta colour difference meter and penetrometer were used to measure the physiological weight, colour and firmness, respectively. The results showed significant difference ($P<0.05$) in the shelf-lives and physiological weight losses for the fruits stored in S_{NR}, S_{NNR} and R_C. Except for the colour of the flesh for Kent, the NIR did not have any significant effect ($P>0.05$) on the colour of the peel or flesh of the Apple. The NIR had no significant effect ($P>0.05$) on the firmness of the peel or flesh for Apple except for Kent. This study showed that the combination of NIR and EC has a potential of improving the shelf-life and quality of mangoes. This technology can provide an applicable solution to storage challenges facing subsistence mango farmers leading to reduced postharvest losses hence improved food security and standard of living.

Keywords: Apple and Kent mangoes, near infrared reflection, evaporative cooling, quality, Kenya

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1 Introduction

Mango is one of the most valuable fruit tree in Kenya. The fruit plays an important role as a source of nutrients (Rathore et al., 2007), income for resource poor farmer, raw material for industries and foreign exchange. In Kenya, the annual mango harvest fluctuates seasonally, with periods of high and low supply. KARI (1994) reported that during the periods of high supply, at least 40% to 45% of mango is spoilt and wasted along the postharvest chain primarily due to inadequate storage facilities. This has reduced the quantity of the fruit avail in the market hence low incoming for farmers.

During the peak season the surplus fruits in the market are disposed by selling them at throw away price for fear of spoilage due to inadequate storage facilities. The adoption of storage technology can significantly reduce the fruit deterioration and spoilage. An effective storage of mangoes can be achieved by controlling storage environment. In the modern storage systems the critical parameters of the storage environment include temperature and relative humidity (Uluko et al., 2006). One of the good management practices aimed at improving the shelf-lives and quality of the fruits during storage is discarding fruits which are damaged or

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diseased. These fruits have reduced shelf-lives because they respire rapidly and more so susceptible to microbial attack leading to increased rate of spoilage (Shitanda and Wanjala, 2006).

In order to address the challenges in mango storage in Kenya, Korir et al. (2014) presented an applicable storage technology which combined near infrared reflection (NIR) and evaporative cooling (EC) to lower temperature of storage environment. This technology is appropriate for remote areas without electricity where modern preservation systems such as refrigerators which rely heavily on electricity are inapplicable. However, the effect of the combination of NIR and EC on quality of mangoes has not been established. Therefore, this study was conducted with the aim of evaluating effect of combination of NIR and EC on quality of mangoes.

2 Materials and methods

2.1 Description of the storage system used

Two identical EC systems were developed in the Department of Agricultural and Biosystems Engineering at Jomo Kenyatta University of Agriculture and Technology. The dimensions of the stores namely length, width and height were 0.84, 0.84 and 1.5 m, respectively. To prevent splash water from entering the store, it was raised 0.4 m above the ground. The main frame of the store was made using timber measuring 10 by 5 cm. The storage chamber was surrounded by a pad made from wire mesh having diameter of 0.24 mm and charcoal. An aluminium sheet with thickness of 0.5 mm was fixed around the internal surface of the storage chamber to prevent charcoal dust from contaminating the stored product. The dimensions of the evaporative pad which included the length, height and thickness were 0.84, 1.1 and 0.1 m, respectively. Inside the storage chamber were shelves made from coffee tray mesh having diameter and spacing of 0.5 and 5 mm, respectively. The side opposite the door was extended to accommodate 12 V fan used to draw ambient air into the store.

The evaporative pads of the two stores were kept moist by water dripping by gravity from plastic pipes having diameter of 12.7 mm horizontally laid on the roof and connected to a 100 L overhead tank raised 2 m above the ground. Gutters below the pads were used to collect water draining from the bottom of the pads to a 100 L temporary storage tank at the ground level. A 12 V shurflo pump (2088-443-144; Mexico) with a capacity of 13.2 L min^{-1} and 2.7 m head was used to recycle the water from the temporary storage tank to the overhead tank. The pump and fan were connected to a solar PV system comprising of a charge controller (Apple 15, Sundaya International Pte., Ltd, Singapore), 70 Ah battery recharged by a 125 W solar panel. The external surfaces of one of the coolers were sprayed with NIR paint (Redusol, Mardenkro Company, Baarle-Nassau, Netherlands). The paint was diluted before application by mixing it with water in the ratio of 1:2.

2.2 Temperature and relative humidity of storage environment for storage system used

The temperature of storage environment for the NIR store (S_{NR}) and non-NIR store (S_{NNR}) ranged from 15.4℃ to 18.6℃ and 16.4℃ to 22.9℃, respectively. The room conditions (R_C) and ambient conditions (A_C) temperatures ranged from 21.6℃ to 25.5℃ and 23.6℃ to 31.9℃, respectively. Figure 1 shows temperature profile of storage environment for S_{NR} compared with S_{NNR}, R_C and A_C. The effect of NIR on temperature of storage environment was significant (P<0.05).

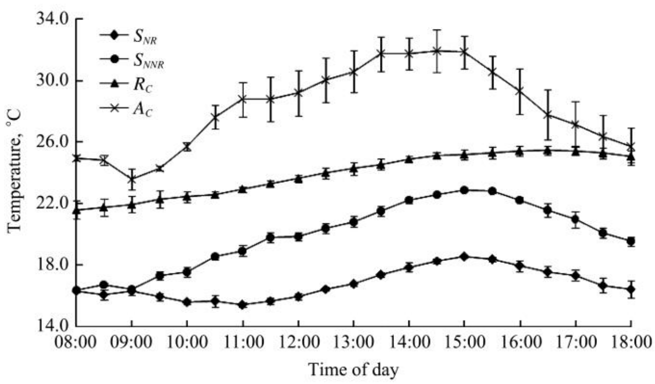

Figure 1 Temperature profiles of storage environment for S_{NR} compared with S_{NNR}, R_C and A_C

The relative humidity of storage environment for S_{NR}, S_{NNR}, R_C and A_C ranged from 58.3% to 88.4%, 53.0% to 87.0%, 56.9% to 61.9% and 51.9% to 74.6%, respectively. Figure 2 presents relative humidity profile of storage environment for S_{NR} compared with S_{NNR}, R_C and A_C. The NIR had significant effect (P<0.05) on the relative humidity of storage environment.

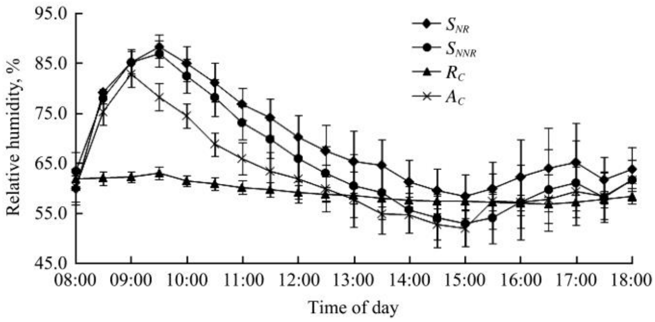

Figure 2 Relative humidity profiles of storage environment for S_{NR} compared with S_{NNR}, R_C and A_C

2.3 Experimental set up

Two mango varieties namely Apple and Kent (Figure 3) were selected based on the results of the baseline survey conducted in the Lower Eastern region of Kenya. Freshly mature fruits were sourced directly from the farmer and three trials were conducted during the season. In each trial the fruits were selected from the farmer's harvest and transported in plastic crates to the experimental site. Harvesting was done in the morning and the fruits transported on the same day and kept in a cool dry place overnight. The fruits were then sorted and cleaned stored in the S_{NR}, S_{NNR} and R_C. The shelf-lives and quality attributes of the fruits namely physiological weight colour and firmness for the fruits stored in S_{NR} (Figure 3) were evaluated against the fruits stored in the S_{NNR}. The R_C was used as a control experiment.

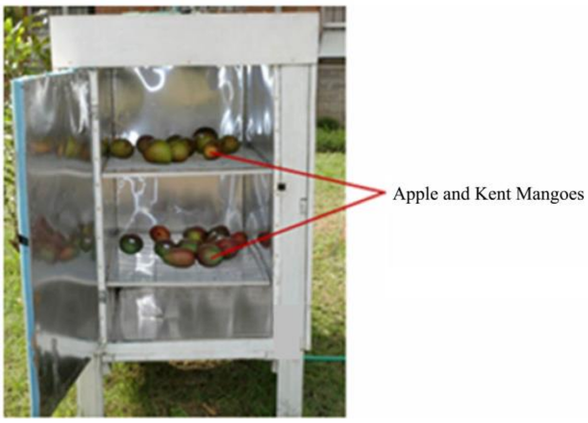

Figure 3 S_{NR} store loaded with mango fruits at the start of experiment

The physiological weight was measured on daily basis using a digital scale (PB3002, Mittler Toledo, Switzerland). The percentage physiological loss in weight was calculated as in the equation $W_l = 100(A–B)/A$, in which W_l, A and B are the percentage physiological loss in weight, weight of a mango fruit before storage and weight of the mango fruit at inspection day, respectively. The colour of the fruits was monitored daily by measuring the colour values L^*, a^*, b^* using the Minolta colour difference meter (CR-200, Osaka, Japan) after calibrating it with a white and black tile. The parameters a^*, b^* and L^* represent the degree of redness to greenness, degree of yellowness to blueness and degree of lightness to darkness, respectively. The hue angle (H°) was determined using McGuire's equations. Based on the computed values for hue angle, the colour of the mangoes was evaluated using a CIE-L.a.b colour chart plot. The firmness of the fruit was measured daily using a penetrometer (CR-100D, Sun Scientific Co. Ltd Japan).

3 Results and discussion

3.1 Effect of NIR and EC on shelf-life

The shelf-lives of the Apple mangoes stored in the S_{NR}, S_{NNR} and R_C were 18 days, 15 days and 9 days, respectively. This implied that shelf-lives of Apple mangoes stored in S_{NR} were extended by 3 days and 9 days compared those stored in S_{NNR} and R_C, respectively. Conversely, the shelf-lives of Kent mangoes stored in the S_{NR}, S_{NNR} and R_C were 24 days, 21 days and 15 days, respectively. This showed that shelf-lives of Kent mangoes stored in S_{NR} were extended the by 3 days and 6 days compared to those stored in S_{NNR} and R_C, respectively. The difference in shelf-lives for the fruit stored in S_{NR}, S_{NNR} and R_C was significant (P<0.05). The shelf-lives of the two varieties were significantly different (P<0.05) under similar storage conditions. Therefore, it can be concluded that shelf-lives of mangoes are also influence by variety. This observation is in agreement with Carrillo et al. (2000) who reported that the shelf-lives vary among the mango varieties.

3.2 Effect of NIR and EC on physiological weight

Figure 4 shows increasing trend in physiological weight loss for Apple mangoes stored in the S_{NR}, S_{NNR} and R_C. At the end of the experiment, the corresponding weight losses were 17.28% ± 0.57%, 24.43% ± 2.45% and 19.03%±1.04%, respectively. Similarly, a progressive weight loss in Kent mangoes was observed during storage (Figure 5). The weight losses of 15.39% ± 1.54%, 18.70% ± 1.27%, and 18.48% ± 0.58% were observed at the end of the experiment for Kent mangoes stored in the S_{NR}, S_{NNR} and R_C, respectively. These results are comparable with that reported by Doreyappa-Gowda and Huddar (2001) and that presented by Rathore et al. (2007) who investigated weight loss in different mango varieties during storage.

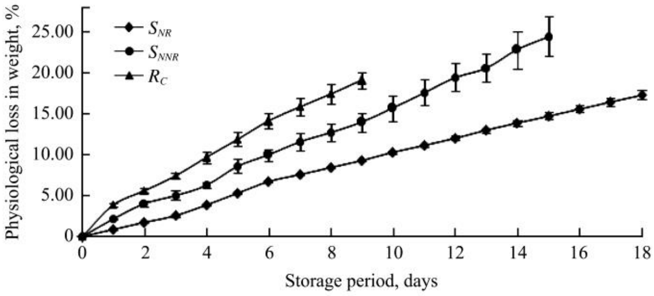

Figure 4 Variation in physiological weight loss with storage period for Apple mangoes stored in the S_{NR}, S_{NNR} and R_C

The physiological weight loss in Apple mangoes stored in the S_{NR} was reduced by 4.64% and 9.77% compared to S_{NNR} and R_C, respectively. Similarly, the weight loss in Kent mangoes decreased by 4.09% and 8.82% compared to the fruit stored in S_{NNR} and R_C, respectively. The difference in weight was significant ($P<0.05$) hence increased income earnings by the farmers particularly if the fruits are sold based on physiological weight. This further implies less shriveling occurring and appearances cannot deteriorate hence increased market value. According to Rathore et al. (2007), physiological loss in weight is due to respiration, transpiration of water through the peel tissue, and other biological changes taking place within the fruit. In this study, the variation in weight loss among the storage methods used was due to difference in temperature and relative humidity of the storage environment which influence rate of water loss however, the influence of variety on weight loss was significant ($P<0.05$).

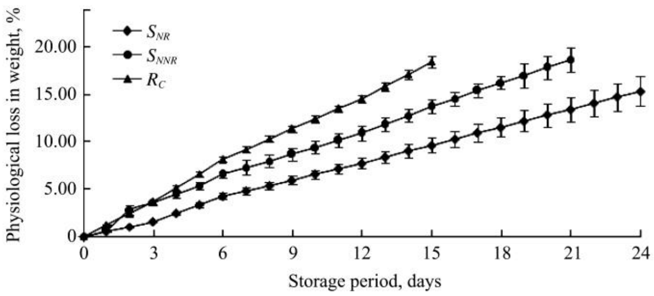

Figure 5 Variation in physiological weight loss with storage period for Kent mangoes stored in S_{NR}, S_{NNR} and R_C

3.3 Effect of NIR and EC on colour

A decreasing trend in the hue angle of the peel indicated a continuous ripening of the fruit during storage. The colour of the peel for Apple mangoes before storage was greenish yellow with hue angle ranging from 105.63° ± 0.90° to 105.90° ± 1.78° but at end of storage it changed to orange yellow with a hue angle of 70.42° ± 0.94°, 70.96° ± 0.63° and 70.84° ± 0.54° for the Apple mangoes stored in the S_{NR}, S_{NNR} and R_C, respectively (Table 1). The effect of NIR on colour of the peel was not significant ($P>0.05$). According to Wills et al. (1982), loss of green colour in mangoes is due to physico-chemical changes by degradation of the chlorophyll structure and increased in carotenoid pigments during storage. Doreyappa-Gowda and Huddar (2001) further reported that the increased in the concentration of carotenoids was responsible for changes in the peel colour for green mature mangoes during storage.

Table 1 Variation in hue angle of the peel with storage period for Apple mangoes stored in S_{NR}, S_{NNR} and R_C

Storage period (days)	S_{NR} (H°)	S_{NNR} (H°)	R_C (H°)
0	105.63 ±0.90^a	105.80 ±1.60^a	105.90 ±1.78^a
1	105.15 ±1.11^a	104.14 ±1.66^a	104.99 ±1.13^a
2	104.65 ±1.42^a	102.52 ±1.82^a	104.14 ±0.68^a
3	103.92 ±1.22^a	100.96 ±2.07^a	103.34 ±0.76^a
4	94.91 ±1.45^a	92.72 ±1.32^a	94.89 ±1.32^a
5	86.61 ±1.69^a	84.14 ±1.34^a	86.97 ±2.06^a
6	78.91 ±2.09^a	76.57 ±1.48^a	79.81 ±2.81^a
7	76.53 ±1.86^a	75.88 ±1.27^a	77.01 ±1.84^a
8	76.10 ±1.68^a	75.21 ±1.05^a	74.19 ±0.94^a
9	75.89 ±1.56^a	74.53 ±0.84^a	70.84 ±0.54^b
10	74.72 ±1.49^a	73.87 ±0.64^a	
11	74.56 ±1.41^a	73.21 ±0.44^a	
12	73.40 ±1.34^a	72.55 ±0.28^a	
13	72.23 ±1.27^a	71.01 ±0.37^a	
14	72.07 ±1.20^a	71.48 ±0.49^a	
15	71.91 ±1.13^a	70.96 ±0.63^a	
16	71.75 ±1.07^a		
17	71.59 ±1.00^a		
18	70.42 ±0.94^a		

Note: Mean values ± standard errors with different superscripts in a row are significantly different at 5% level of significance.

Similarly, a decreasing trend in hue angle of the flesh with storage time was observed in Apple mangoes during storage (Table 2). The colour of the flesh for the Apple mangoes before storage was greenish yellow with hue angle ranging from 97.44° ± 0.15° to 98.05° ± 0.56° while at the end of storage period was orange yellow with hue angle of 76.41° ± 0.06°, 76.62° ± 0.76° and 75.28° ± 0.52° for the fruit stored in the S_{NR}, S_{NNR} and R_C, respectively

(Table 2). The analysis of results did not show any significant effect (P>0.05) of NIR on the colour of the flesh however, the results corroborate with that presented by Doreyappa-Gowda and Huddar (2001) who investigated changes in colour of the pulp for different varieties of mangoes during storage. According to Wills et al. (1982) the breakdown of chlorophyll structure and formation of carotenoid pigments are responsible for the changes in the colour of the pulp during storage.

Table 2 Variation in hue angle of the flesh with storage period for Apple mangoes stored in the S_{NR}, S_{NNR} and R_C

Storage period (days)	S_{NR} (H°)	S_{NNR} (H°)	R_C (H°)
0	97.44 ±0.15[a]	97.78 ±0.20[a]	98.05 ±0.56[a]
1	90.22 ±1.12[a]	87.58 ±0.96[a]	91.02 ±0.89[a]
2	82.45 ±1.60[a]	80.63 ±1.88[a]	86.05 ±0.67[a]
3	83.27 ±0.78[a]	80.23 ±2.28[a]	82.37 ±0.27[a]
4	81.92 ±0.53[a]	80.17 ±1.41[a]	81.65 ±0.53[a]
5	80.61 ±0.29[a]	80.15 ±1.11[a]	80.94 ±0.79[a]
6	79.33 ±0.05[a]	79.73 ±1.78[a]	80.22 ±1.06[a]
7	78.84 ±0.03[a]	79.39 ±0.79[a]	78.49 ±0.86[a]
8	78.36 ±0.01[a]	78.86 ±0.47[a]	76.84 ±0.68[a]
9	77.90 ±0.01[a]	78.35 ±0.17[a]	75.28 ±0.52[b]
10	77.44 ±0.04[a]	78.06 ±0.27[a]	
11	77.00 ±0.06[a]	77.77 ±0.37[a]	
12	76.56 ±0.09[a]	77.48 ±0.46[a]	
13	76.54 ±0.08[a]	77.19 ±0.56[a]	
14	76.51 ±0.08[a]	76.90 ±0.66[a]	
15	76.49 ±0.07[a]	76.62 ±0.76[a]	
16	76.46 ±0.07[a]		
17	76.44 ±0.06[a]		
18	76.41 ±0.06[a]		

Note: Mean values ± standard error with different superscripts in a row are significantly different at 5% level of significance.

The peel colour for Kent mangoes before storage and at the end was greenish yellow with hue angle ranging from 112.91° ± 1.38° to 124.75° ± 1.53°. The slight variation in the hue angle implied that peel colour was unreliable attribute for monitoring the quality of the fruit during storage. Therefore, changes in the colour of the flesh of the fruit were investigated. The colour ofthe flesh of the fruit before storage was greenish yellow with hue angle that ranged from 99.49° ± 0.24° to 100.47° ± 0.60° while at the end of storage was orange yellow with hue angle of 78.71° ± 0.03°, 79.41° ± 0.51° and 79.24° ± 0.30° for the fruit stored in the S_{NR}, S_{NNR} and R_C, respectively (Table 3). The effect of NIR on colour of the flesh was significant (P<0.05). Doreyappa-Gowda and Huddar (2001) reported that the changes in the pulp colour of mangoes are due to the development of carotenoids during storage.

Table 3 Variation in hue angle of the flesh with storage period for Kent mangoes stored in the S_{NR}, S_{NNR} and R_C

Storage period (days)	S_{NR} (H°)	S_{NNR} (H°)	R_C (H°)
0	99.49 ±0.24[a]	100.18 ±0.55[a]	100.47 ±0.60[a]
1	98.39 ±0.12[a]	97.69 ±0.28[a]	94.98 ±0.24[b]
2	97.32 ±0.00[a]	95.51 ±0.10[b]	90.67 ±0.04[c]
3	96.26 ±0.12[a]	93.57 ±0.01[b]	87.21 ±0.06[c]
4	94.71 ±0.02[a]	93.50 ±0.31[a]	87.61 ±0.02[b]
5	93.36 ±0.14[a]	93.45 ±0.57[b]	87.97 ±0.01[c]
6	92.19 ±0.23[a]	93.40 ±0.81[a]	88.32 ±0.04[b]
7	91.66 ±0.16[a]	92.54 ±0.53[a]	87.07 ±0.26[b]
8	91.14 ±0.10[a]	91.69 ±0.27[a]	85.84 ±0.55[b]
9	90.63 ±0.05[a]	90.86 ±0.03[a]	84.62 ±0.82[b]
10	89.29 ±0.09[a]	89.41 ±0.06[a]	83.74 ±0.60[b]
11	88.04 ±0.19[a]	87.97 ±0.08[a]	82.85 ±0.39[b]
12	86.87 ±0.28[a]	86.54 ±0.09[a]	81.95 ±0.19[b]
13	86.24 ±0.25[a]	86.15 ±0.09[a]	81.08 ±0.23[b]
14	85.59 ±0.22[a]	85.76 ±0.09[a]	80.18 ±0.27[b]
15	84.94 ±0.19[a]	85.36 ±0.09[a]	79.24 ±0.30[b]
16	84.28 ±0.16[a]	84.96 ±0.08[a]	
17	83.61 ±0.14[a]	84.56 ±0.08[b]	
18	82.93 ±0.11[a]	84.15 ±0.07[b]	
19	82.25 ±0.08[a]	83.74 ±0.07[b]	
20	81.55 ±0.06[a]	82.39 ±0.06[b]	
21	80.85 ±0.03[a]	79.41 ±0.51[a]	
22	80.15 ±0.01[a]		
23	79.43 ±0.01[a]		
24	78.71 ±0.03[a]		

Note: Mean values ± standard errors with different superscripts in a row are significantly different at 5% level of significance.

3.4 Effect of NIR and EC on firmness

The firmness of the peel for Apple mangoes decreased significantly during storage. Figure 6 presents changes in the peel firmness during storage of Apple mangoes in S_{NR}, S_{NNR} and R_C. The average firmness of the peel for Apple mangoes at the beginning of the experiment was 40.80 ± 0.55 N and decreased to 3.53 ± 0.06 N for the fruit stored in the S_{NR} and S_{NNR}; 3.50 ± 0.12 N for the fruit stored in the R_C at the end of experiment.

A rapid decline in peel firmness was observed within first 3 days and then stabilized until end of the experiment for the Apple mangoes stored in the R_C. The decrease in firmness was high within the first 6 days and then became gradual until the end of experiment for the fruit stored in S_{NR} and S_{NNR} (Figure 6). Therefore, this indicated that the rate of softening for the fruit stored in the R_C was higher compared with those stored in the S_{NR} and S_{NNR}.

Figure 7 shows changes in firmness of the peel for Kent mangoes during storage. The average value of firmness before storage was 66.88±2.81 N and decreased to 9.54 ±0.66 N, 9.54 ±0.68 N and 9.46 ±0.23 N at the end of experiment for the fruit stored in the S_{NR}, S_{NNR} and R_C, respectively. The decrease in firmness with time indicated the softness of the fruit as it ripens. The decrease in firmness was rapid in the first 9 days, 15 days and 18 days for the fruit stored in the R_C, S_{NNR} and S_{NR}, respectively and then stabilized until the end of experiment. This indicated that the decline in firmness was lower in S_{NR} by 3 days and 9 days compared to S_{NNR} and R_C, respectively.

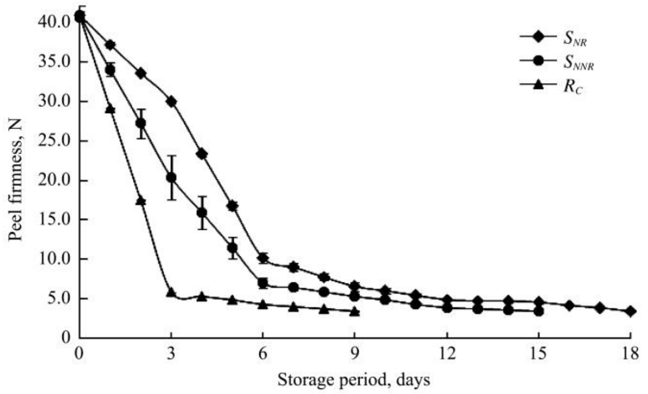

Figure 6 Variation in firmness of the peel with storage period for Apple mangoes stored in the S_{NR}, S_{NNR} and R_C

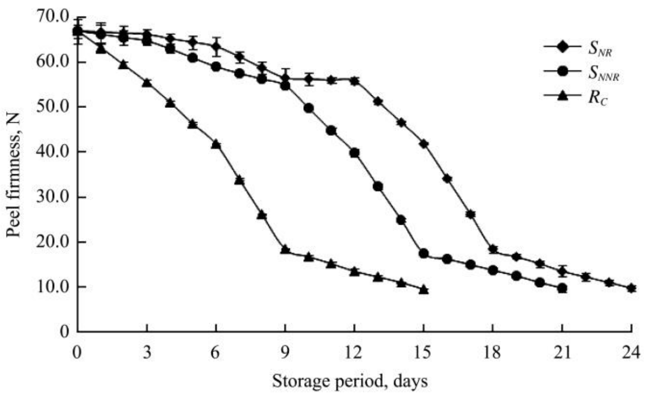

Figure 7 Variation in firmness of the peel with storage period for Kent mangoes stored in the S_{NR}, S_{NNR} and R_C

During the experiment the fruits were handled in a similar way hence the softening was due to breakdown of pectic substances and changes in the cells wall structure. According to Weichmann (1987) reduction in firmness of mangoes during storage might be due to the breakdown of insoluble pectic substances to soluble forms by a series of physico-chemical changes due to enzymatic reactions. Similarly, Kalra et al. (1995) reported that the rapid decline of firmness in the mangoes during ripening is due to changes in the structure of the pectin polymers of cells wall which later stabilized indicating completion of ripening. In addition, Hosakote et al. (2006) reported that ripening of mangoes is accompanied by a series of biochemical changes resulting in gradual textural softening. In addition, Jha et al. (2006) further indicated that the firmness of the mango fruits remained almost constant over the period of growth and it decreased after attaining the maturity.

A decreasing trend in firmness of the flesh was observed for Apple mangoes stored in the S_{NR}, S_{NNR} and R_C (Figure 8). The average firmness of the flesh for Apple mangoes at beginning of the experiment was 25.33 ±0.23 N. This value however, decreased to 0.95 ±0.07 N, 0.98 ±0.10 N and 0.98 ±0.15 N at the end of for the experiment for the fruit stored in the S_{NR}, S_{NNR} and R_C, respectively. The decline in firmness of the flesh was high within the first 3 days and became gradual until the end of the experiment. The figure further revealed that decreased in firmness was lower for the fruits stored in the S_{NR} compared with those stored in S_{NNR} and R_C. According to Kalra et al. (1995) the decline in firmness is due changes in the structure of the cell wall. Similar observation was reported Hosakote et al. (2006), Goulao and Oliveira (2008) who reported that the loss of firmness of the pulp is attributed to physiological and biochemical changes which include conversion of starch to sugars, biosynthesis of flavour and aromatic volatiles, changes in the cell wall ultra-structure and metabolism.

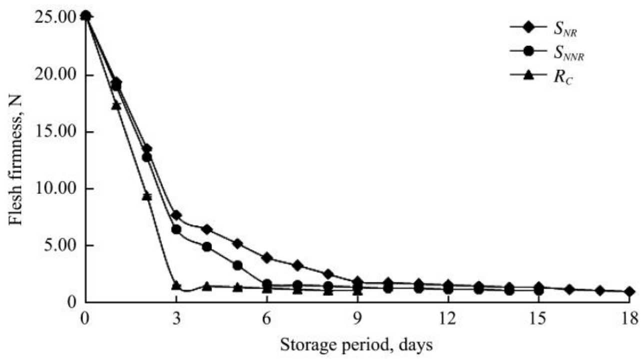

Figure 8 Variation in firmness of the flesh with storage period for Apple mangoes stored in the S_{NR}, S_{NNR} and R_C

Figure 9 presents variation in firmness of the flesh for Kent mangoes during storage in the S_{NR}, S_{NNR} and R_C. The average firmness value of the flesh for the fruit was 47.29 ± 0.35 N at the start of experiment of which decreased to 1.59 ±0.24 N, 1.51 ±0.01 N and 1.57 ±0.09 N at the end of the experiment for the fruit stored in the S_{NR}, S_{NNR} and R_C, respectively. These results are comparable to those presented by Hosakote et al. (2006) and Jha et al. (2010) who investigated changes in firmness of the flesh for different varieties mango fruits during storage. A lower decline in firmness of the Kent mangoes was also observed for the fruit stored in the S_{NR} as compared to those stored in the S_{NNR} and R_C. The fruits were handled in a similar way hence the decrease in flesh firmness was therefore due to change of starch to sugars, formation of flavour and aromatic volatiles, alteration of the cell wall structure, and metabolism. Based on results analysis, it can be concluded that the NIR had no significant effect (P>0.05) on the firmness of the peel or flesh for Apple except for Kent.

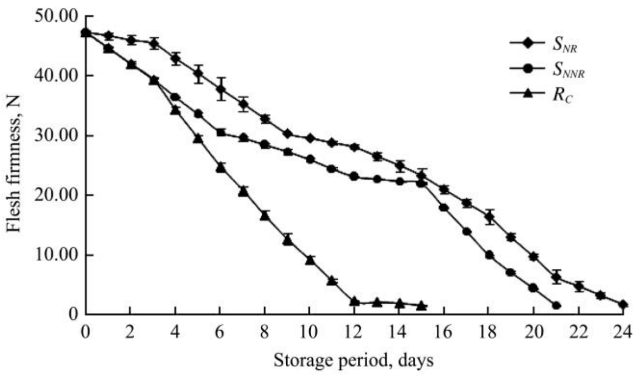

Figure 9 Variation in firmness of the flesh with storage period for Kent mangoes stored in the S_{NR}, S_{NNR} and R_C

4 Conclusions

This study concluded that storage of mangoes in S_{NR} significantly improves the shelf-lives and quality of the fruit compared with storage in S_{NNR} and R_C. This implies that the combination of NIR and EC is a technology that can provide an applicable solution to storage challenges in mangoes leading to significant reduction in postharvest losses hence improved food security and standard of living.

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