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EFFECT OF DIFFERENT PRE- AND POST-HARVEST TREATMENTS ON QUALITY AND SHELF LIFE OF GUAVA (*Psidium guajava*)

C.K.D. WELLALA, M.K. THANTIRIGE and S.M.I.P.G. BANDARA

Fruits Crops Research and Development Centre, Horana, Sri Lanka

ABSTRACT

The effect of different pre- and post-harvest treatments on the quality and shelf life of guava (*Psidium guajava*) varities Horana White, Kanthi, Horana Red and Pubudu was evaluated. Fruit growth curves were drawn to identify the correct time of applying pre-harvest treatments. Fruit maturity indices were determined. Fruits at commercial maturity were subjected to four different post-harvest treatments namely, storage at ambient temperature (27±3°C), low-density polyethelene (LDPE) packaging at ambient temperature, wax coating (2%) at ambient temperature and refrigerated storage (6-10°C). The pre-harvest treatment consisted of sprayings, 4% of calcium nitrate against water (control). Physico-chemical parameters measured included fruit firmness, skin colour, total soluble soilds (TSS), titratable acidity (TAA), length, width, weight and age. Guava showed a double-sigmoid growth and exponential growth phase for different varieties, during which pre-harvest treatment to be applied. Rapid ripening and high rate of senescence were observed with fruits kept at the ambient temperature and more controlled ripening occurred in the refrigerated fruits. The LDPE packaging and wax coating at ambient temperature showed a prolonged shelf life of fruits kept at room temperature. The LDPE packaging was successful in guava var. Pubudu with acceptable flavor and texture. Pre-harvest Ca spraying resulted in greater fruit firmness and beneficial effects that increased with duration of storage. The Ca treatment did not have a signficant ($p>0.05$) effect on normal ripening of guava varieties considered.

KEY WORDS: Guava, LDPE, Wax coating, Refrigeration, Calcium nitrate treatment

INTRODUCTION

Guava (*Psidium guajava*) has become a popular fruit in local markets of Sri Lanka. It has a good potential for further expansion with its high productivity hardiness and adaptability to different climatic conditions, and high nutritive and medicinal value (Morton, 1987) beneficial to the producers and consumers. However, the quality of the fruit at the time it reaches the consumer is questionable, which is a major constraint in the market that may influence customer acceptability. The short shelf life is the main factor of quality deterioration in guava, caused by the adverse physiological changes such as loss of weight due to respiration and transpiration, rapid softening of the flesh and its susceptibility to microbial attack (Tucker, 1993) resulting in high post-harvest loss.

In order to preserve the quality of the fruits after harvesting and to prolong the shelf life, various techniques and treatments can be adopted. Cold storage or refrigeration is one common technique in bulk transport, which delays fruit quality degradation by reducing its biological and chemical activity (Thompson, 1985; Hernandez-Munoz *et al.*, 2008). Waxing and polythene packaging are more cost-effective techniques, in which the atmosphere inside the fruit is modified in order to extent the storage life (Liu, 1988; Hernandez-Munoz *et al.*, 2008). Higher firmness is considered a valuable parameter in reducing post-harvest damages when the fruit is going through the marketing channels and when the consumer prefers crispiness. Sugars and organic acids form a major contribution to the overall flavor of the fruit (Burton, 1982).

In addition, some pre-harvest treatments are also effective in delaying the ripeness, improving fruit quality and yield. Proper supply of nutrients is one way of pre-harvest treatments (Prado *et al.*, 2005). Calcium is the most important element determining the quality of fruits (Bakshi *et al.*, 2005). About 60% of the total cellular calcium is located in the cell wall, where it exerts its stabilizing function (Tobias *et al.*, 1993; Conway *et al.*, 2002). Furthermore, Ca is found to be beneficial in reducing ethylene and CO_2 production and the incidence of postharvest diseases (Conway and Sams, 1987). High Ca fruits can be transported better and remained in good conditions longer (Miklos, 1989). Chamel (1989) showed that Ca can be applied directly to the fruit surface to be effective. Singh *et al.* (1993) has shown that cells of the fruits have high absorption rate when they grow bigger in size. Therefore, it is important to identify the phase or stage of fruit growth, where the cells grow bigger.

Maturity at harvest also has an effect on the eating and keeping quality. If the fruit is harvested at over ripened stage, the eating quality attributes of the fruit is better, but the keeping quality is lower. If the fruit is harvested at immature stage, the fruits will have low eating quality, but longer shelf life (Liu, 1988). Fruit maturity at harvest, required by market (commercial maturity) (Wills, 1989) is required to be identified and is determined by the variety, the stage at which the fruits are to be eaten or processed (Kader, 1986) and the distance to the market (Liu, 1988). Hence, the objective of the present study was to evaluate the effect of different pre- and post-harvest treatments on the quality and shelf life of guava. Furthermore, the fruit growth and development curves were studied and the correct harvesting stage of four recommended varieties of guava namely, Horana White, Horana Red, Kanthi and Pubudu having high potential for commercial cultivation were also identified.

MATERIALS AND METHODS

The research was conducted in the Fruit Crops Research and Development Centre, Horana, Sri Lanka during 2008 to 2011.

Experiment 1: Determination of maturity indices

The correct harvesting maturity (commercial maturity) that extends the shelf life of guava fruits (*Psidium guajava*) with good organoleptic quality was determined separately for . var. Horana White (HW), Horana Red (HR), Kanthi (Ka) and Pubudu (Pu) . Twenty five fruits of each variety at four maturity stages ranging from green to yellowish green were analyzed for both physico-chemical parameters namely, skin colour, weight, length, width and firmness, Total Soluble Solids (TSS) content and Tritratable Acidity (TAA). The skin colour was determined by using the colour charts of the Royal Horticultural Society, London, 2001. Fruit weight was measured by using a top loading balance. The length (axis between the insertion of the peduncle and the petiole scar) and the transverse diameter (axis perpendicular to the length in the middle part of the fruit) were also measured using a venire caliper. The firmness indicated in kg was determined with the aid of a Penetrometer (FT 327, EFFEGI, Italy) with a tip diameter of 8 mm and from the opposite sides along the fruit equatorial region. The TSS content (^{o}Brix) of the pulp was determined by using a hand-held Refractometer (ATAGO, Japan). TAA was determined by AOAC (1995) methods.

Experiment II: Determination of effect of post-harvest treatments on storage life

Four varieties of guava harvested at commercial maturity with stalks, were subjected to simple, farmer convenient and consumer safe post-harvest treatments namely, (i) storage at ambient temperature (control; $27 \pm 3^{\circ}C$) (ii) packaging in low-density polyethelene (LDPE) bags (13 x 15 cm, 200 gauge) and storage at ambient temperature (iii) surface coating with 2 % edible gelatin wax and storage at ambient temperature (iv) storage at $6\text{-}10^{\circ}C$ without packaging. Fruits subjected to above treatments were positioned in a way that pedicle-end of the fruit is oriented vertically upwards. The treatments were arranged in a CRD with three replicates. The texture, TSS, TAA and colour of the guava fruits of the four varieties were analyzed in two-day intervals, until the fruits reached the fully decayed stage, where they lost the eating quality.

Experiment III: Developing fruit growth curves of four varieties of guava

Length and width of guava fruits were measured at weekly intervals from fruit set to fully ripen stage. A sample of 100 fruits was used from each variety. The average length and width of fruits were calculated and plotted against time.

Experiment IV: Determination of effect of $Ca(NO_3)_2$ on the quality and shelf life of Horana White, Horana Red and Kanthi varieties

Calcium nitrate $(CaNO_3)_2$ was applied to var. HW, HR and Ka separately during the exponential growth phase of the fruits, and was sprayed at three concentrations (1, 2 and 4 %) against the water-sprayed control treatment. Each concentration was applied to three trees selected from three plots in a RCBD. The treatment applications were done, at three times in three-day intervals and at rate of one L/plant at a time. Fruits were harvested at commercial maturity as determined in Experiment I and stored at ambient conditions and fruit quality parameters (texture, TSS and TAA) were analyzed at one and two-day intervals until the end of shelf life.

Statistical analysis

Data were subjected to Analysis of Variance (ANOVA) using SAS computer software package and the least significant difference (LSD) was used to compare the treatment means at $p=0.05$.

RESULTS AND DISCUSSION

Determination of commercial maturity indices

Fruit firmness declined significantly during fruit ripening (Table 1). At the early maturity (stage 1), fruits were green, hard and a significant decline in firmness occurred at the colour turning stage (stage 2) in var. HR, HW and Ka, and further reduced with early ripening (stage 3) and ripening (stage 4). The textural changes during the ripening of most fruits are found to be largely a result of cell wall degradation or dissolution of the pectin-rich middle lamella region of the cell wall (Tucker, 1993). The var. Pu was exceptional where it had acceptable better texture (crispiness) even at fully ripen stage, which is a good quality character, and higher shelf life.

The TSS content increased with the fruit ripening in all 4 varieties of guava, but not significant in var. Pu (Table 1). Rodriguez *et al.* (1971) also observed a gradual increase in TSS and total sugars during fruit ripening. Starch and sucrose change into glucose during fruit ripening (Wills *et al.*, 1981).

Citric acid is the predominant organic acid in guava (Burton, 1982). The TAA of var. HW, Ka and HR showed a significant decline ($p<0.05$ from early maturity to colour turning point, and non significant decline thereafter ($p>0.05$; Table 1). Organic acids contribute to flavor of unripen fruits and their level reduces in ripened fruits. Decrease in the acidity may be the result of respiration (Burton, 1982). Thus, TSS/TAA, which increased during ripening, is a good indicator of ripening that presents the balance between sweetness and acidity.

Table1. Fruit maturity parameters of different varieties of guava

Variety	*Maturity stage*	*Firmness (kg)*	*TSS (°Brix)*	*TAA (%)*	*TSS/TAA*	*Skin color*	*Fruit length and width (cm)*
HW	1	13.0a	8.5b	0.45a	18.8c	YG144B	6.10±0.50 6.39±0.43
	2	12.2b	10.5a	0.39b	27.2b	YG145B	6.29±0.46 6.50±0.49
	3	4.1c	11.1a	0.38b	29.3b	YGN144D	6.87±0.32 7.09±0.40
	4	2.6d	11.3a	0.31c	36.4a	YGN144B	6.88±0.25 7.10±0.34
	p	0.001	0.002	0.001	0.000	-	-
	cv %	4.3	5.0	5.5	5.3		
Ka	1	16.8a	7.8b	0.49a	16.0c	YG144B	6.28±0.32 6.80±0.41
	2	9.8b	8.5b	0.36b	23.8b	YG145A	7.10±0.32 7.42±0.24
	3	4.0c	10.1a	0.36b	28.3a	YGN144D	7.35±0.56 7.67±0.62
	4	3.0c	9.7a	0.31b	31.1a	YGN144B	7.34±0.43 7.69±0.24
	p	0.000	0.002	0.006	0.000	-	-
	cv %	2.4	4.7	8.7	6.4	-	-
HR	1	15.2a	6.7c	0.65a	10.4d	YG144A	5.42±0.25 5.20±0.42
	2	12.4b	8.5b	0.52b	15.4c	YG144C	5.70±0.45 5.32±0.23
	3	3.6c	10.3a	0.50b	20.5b	YGN144B	5.82±0.23 5.41±0.12
	4	2.3d	11.1a	0.46b	23.7a	YG153D	5.80±0.23 5.42±0.34
	p	0.000	0.000	0.002	0.000	-	-
	cv %	7.5	4.9	5.4	4.4	-	-
Pu	1	15.7a	8.3a	0.43a	19.2c	YG144C	10.34±0.56 7.31±0.43
	2	13.0b	8.5a	0.34b	25.5b	YG144D	11.08±0.09 9.23±0.38
	3	8.6c	8.6a	0.29c	29.0ab	YGN144D	11.86±0.22 9.15±0.24
	4	7.3d	9.0a	0.28c	32.5a	YG150C	11.91±0.44 9.30±0.34
	p	0.001	0.81	0.000	0.005	-	-
	cv %	4.9	10.4	6.1	8.5	-	-

Within each column, means followed by the same letter are not significantly different at p=0.05

The colour turning stage was selected as the ideal stage of harvesting of guava var. HW, HR, Ka and Pu, where it has acceptable firm texture, and higher TSS compared to fruits at early maturity. Acidity of fruits at the colour turning stage reduced to a significantly lower level ($p<0.05$) than those at early maturity (Table 1) and remained the same from the colour turning stage to early ripening. Hence, the TSS/TAA showed a large and significant increment from stage 1 to 2 (Table 1). Once the maturity standards were developed, in terms of internal fruit quality parameters (texture, TSS and TAA), the skin colour, average weight and size (average length and width) of fruit were also identified as harvesting standards (Table 1). The colour is changing from dark green to whitish green at colour turning point followed by yellowish green and yellow, and is associated with the disappearance of chlorophyll. This colour change is the most important criteria in deciding the harvest maturity. Use of harvesting standards would be useful for guava growers as they can use them to prolong the keeping quality and retain eating quality. However, the fruit age varied depending on the fruiting season and variety together with the fruit size and weight. The climatic conditions may affect for these seasonal variations. Therefore, the fruit age at maturity cannot be considered as a harvesting indicator.

Comparison of different postharvest treatments

Out of the four varieties studied, var. Pu had the highest shelf life followed by HW, HR and Ka (Table 2). Fruits stored at ambient temperature had a rapid ripening and higher rate of senescence than those stored at lower temperatures. Guava is a climacteric fruit (Morton, 1987; Azzolini *et al.*, 2005). Those fruits displayed a characteristic peak of respiratory activity and during ripening, substrates are used to produce energy to run cellular processes thus keeping the cells alive (Tucker, 1993). Once the available substrates are exhausted, the decaying might start thus, reducing the rate of respiration. This is an important consideration in extending the post-harvest quality. Factors within the fruits and as well as storage conditions determines the rate of respiration, of which temperature, relative humidity and atmospheric composition are the important in postharvest storage (Brown, 1985).

Table 2. -Fruit shelf life and days with optimum eating quality characteristics of fruits subjected to four post-harvest treatments.

Variety	*Shelf life and (days with optimum eating quality)*			
	Ambient conditions	*Packaging in LDPE*	*Wax coating*	*Storing in cold storage*
Horana White	8 (4)	10 (6)	10 (6)	16 (12)
Horana Red	8 (4)	10 (6)	10 (6)	14 (12)
Kanthi	8 (5)	8 (4)	8 (6)	14 (10)
Pubudu	10 (8)	16 (12)	-	-

When fruits were kept under ambient conditions (without controlling the environmental factors), the ripening and respiration of fruits may occur at a rate similar to natural conditions. As a result, fruits decayed quickly, and the fruit quality attributes deteriorated rapidly. Osman and Ayub (1997) reported that shelf life of guava fruits of the Kampuchea cultivar stored at room temperature (27±3°C) and 60-80 % RH was only one week. Pu was exceptional, where it had a shelf life of 10 days and optimum eating quality for 8 days.

The LDPE (gauge 200) is a semi-permeable plastic package that creates a modified atmosphere is created within once a fruit is sealed in such packing, depending on the rate of respiration and permeability of the film. Respiration rate as well as ethylene production can be controlled within the modified atmosphere (Kader *et al.*, 1989). Mohamed and Kyi (1994) studied effect of various surface treatments on the storage life of guava and suggested that LDPE was the most effective in maintaining the fruit firmness. Reduction of fruit desiccation and shriveling are among other advantages in modified atmosphere packaging. The LDPE packaging could extend the shelf life for guava fruits by 2 additional days in var. HW and HR and 5 days in Pu without a significant loss in the texture of fruits. However, a marginal fermented taste was developed after 6 days in var. HW and HR, 4 days in Ka, and 12 days in Pu. Off-flavor development is a problem in modified atmosphere. If O_2 levels fall too low (below 1-3%) anaerobic reactions can occur resulting in off-flaours, abnormal ripening and spoilage where the rates depend on the produce and storage temperature (Wills *et al.*, 1981; Kader, 1986; Singh, 2010). Ben-Yehosuna *et al.* (1993) showed that poorly designed packaging becomes anaerobic or develops unacceptable levels of CO_2 before equilibrium is achieved. Therefore, high technical assistance is recommended before packing guava in polythene.

Waxing is also a useful technique in generating modified atmosphere conditions inside the fruit, in order to extend the shelf life (Gallo *et al.*, 1999; Hernandez-Munoz *et al.*, 2008). Gelatine was used for the coat as it was readily available in the market and is water soluble forming a flexible, clear and oxygen-permeable film (Genadios *et al.*, 1993). Eventhough geletine was effective in lengthening the storage life of var. HW and HR (Table 2), it was not effective in var. Ka. there was a difficulty in deciding on the ideal thickness of the coat to have an equilibrium in respiration and gas diffusion rates. However, waxing was effective in controlling the transpiration water loss (Liu, 1988) avoiding skin shriveling thus resulting in a glossiness of fruits after applying gelatin wax, which could increase the market value. The external appearance was improved in var. HR than in other varieties since it has a more uniform surface.

Refrigeration is one of the most effective ways in extending the post-harvest storage life if economic conditions permit. Temperature management is the principle in reduction of rate of respiration, transpiration, enzymatic activity and growth and development micro-organisms (Brown and Wills, 1983). Fruit quality attributes were maintained for a longer period with optimum eating quality compared to other methods (Table 2). Osman and Ayub (1997) reported that shelf life of guava cultivar "Kampuchea" could be extended when stored at the optimum conditions of 0-10°C. However, the major barriers in cold storage in addition to the cost factor is the water condensation on the surface of the fruit when the cold fruit is exposed to warm air, which may cause rapid deterioration of fruits.

The fruit firmness of four varieties of guava showed a significant and gradual decline from harvesting to end of shelf life except those treated with gelatin wax (Table 3). Fruit penetration may have become difficult with the wax. Hardening of fruit surface could be the reason for the sudden increase in texture in wax-coated fruits. Fruits kept at cold conditions had a more controlled reduction in firmness, which is beneficial in the long run for bulk transportation and storage of guava. Fruits stored at ambient temperature without any treatment (control) showed a gradual ripening up to the second to fourth day as indicated by the increase in TSS and fruit senescence thereafter. Fruits stored at refrigerated conditions also showed an increase in TSS with time, but ripening was more controlled than that of the untreated fruits (Table 3). The modified atmosphere has some negative impact on the ripening process as shown in fruits packaged in LDPE and coated with wax, where a gradual decrease in TSS occurred irrespective of the variety. Abnormal ripening due to low O_2 levels may be the reason for poor ripening (Kader, 1986 ; Singh, 2010). The titratable acidity of fruits showed a decline during storage (Table 3). The loss of acidity may accompany the ripening appears from the use of organic acids as respiratory substrates via Krebs trycarboxylic cycle (Burton, 1982).

Fruit growth curves

The growth pattern of the four guava varieties were similar and was double sigmoid. However, the time taken for completing the growth was different in the four varieties (Figure 1). The initial rapid growth, which started from flower opening, extended up to two to six weeks depending on the variety, and was followed by a short slow growth phase and minor growth peak. Therafter an exponential growth of length started at about 91 days in the var. HW and Ka, 65 days in HR and 98 days in Pu and lasted until ripening. One special character in var. HW, Ka and HR was the increased rate of growth of the width of the fruit than the length, during this phase (Figure 2). The cell size increases in this phase is particularly due to the increase of dry weight and sucrose concentration (Miura, 1990). Singh *et al.* (1993) showed that the cell has high absorption rate during the rapid increase in cell size. The cells expansion due to sink activity may be vital for absorbing Ca and this phase can be used for applying pre-harvest treatments.

Table 3. Changes in fruit texture, TSS and TAA with the time in different postharvest treatments of four different varieties

Variety	Days from har	Fruit firmness (Kg)				TSS (°B)				TAA (%)			
		Amb.	LDPE pack.	Wax coat.	Cold stor.	Amb.	LDPE pack.	Wax coat.	Cold stor.	Amb.	LDPE pack.	Wax coat.	Cold stor.
	0	12.2a	12.2a	12.2a	12.2a	10.5a	10.5a	10.5a	10.5a	0.39a	0.39a	0.39a	0.39a
	2	8.6b	10.1b	11.8a	9.8b	11.2a	9.2b	9.2b	10.3a	0.37a	0.32b	0.32b	0.34b
	4	5.2c	8.1c	9.9b	8.4c	9.7b	8.5c	8.7b	9.3b	0.28b	0.31bc	0.27c	0.34b
	6	3.2d	5.2d	7.1c	7.8d	7.3c	8.2c	8.2c	9.3b	0.27b	0.29c	0.27c	0.29c
	8	2.5d	3.1e	5.6d	6.3e	6.2d	6.8d	7.5d	9.2b	0.24b	0.24d	0.24c	0.29c
HW	10		2.2f	5.2e	6.2e		5.7e	6.9e	8.7bc		0.22d	0.24c	0.29c
	12				5,2f				8.3c				0.30c
	14				4.2g				7.7d				0.31bc
	16				3.5h				6.2e				0.31bc
	p	0.00	0.000	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
	0	9.8a	9.8a	9.8a	9.8a	8.5c	8.5b	8.5ab	8.5bc	0.42a	0.37ab	0.37a	0.37a
	2	7.7b	7.9b	10.4a	8.6b	10.1ab	9.7a	8.7a	9.1a	0.37ab	0.42a	0.35b	0.3c
	4	6.7c	7.5c	7.6b	7.6c	10.9a	8.2b	8.0b	9.3a	0.32bc	0.32bc	0.38ab	0.34b
	6	5.0d	5.6d	6.8b	6.8d	9.2bc	6.9c	7.2c	9.0ab	0.3c	0.3c	0.40a	0.39a
Ka	8	3.1e	3.7e	4.8c	6.0e	8.5c	5.9d	6.9c	8.4cd	0.3c	0.29c	0.38ab	0.34b
	10				6.0e	7.1d			7.9d				0.33b
	12				5f				7.0e				0.32bc
	14				4.2g				6.6e				0.33b
	P	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.002	0.002	0.04	0.000
	0	12.4a	12.4a	12.4a	12.4a	8.5b	8.5a	8.5a	8.5b	0.52a	0.52a	0.52b	0.52a
	2	10.0b	9.7b	12.73a	10.3b	9.1a	8.3a	8.4a	8.7b	0.49a	0.51ab	0.56a	0.46b
	4	8.6c	9.0b	10.0b	9.4c	8.5c	7.7b	8.7a	8.7b	0.39b	0.51ab	0.46c	0.44bc
	6	6.1d	6.7c	8.3c	8.3e	7.7d	7.2bc	8.0a	8.7b	0.33c	0.49b	0.44c	0.45b
HR	8	4.0e	4.7d	6.4d	7.0e	6.5e	6.9c	7.0c	9.5a	0.31c	0.44c	0.37d	0.44bc
	10		3.0e	4.3e	7.2e		6.1d	6.1d	8.6b		0.37d	0.33e	0.41cd
	12				6.5e				7.2c				0.41cd
	14				4.2f				6.6d				0.39d
	p	0.000	0.00	0.000	0.00	0.00	0.00	0.00	0.000	0.00	0.000	0.000	0.000

Table 3. Changes in fruit texture, TSS and TAA with the time in different postharvest treatments of four different varieties (continued)

Variety	*Days from har*	*Fruit firmness (Kg)*				*TSS (°B)*				*TAA (%)*			
		Amb.	*LDPE pack.*	*Wax coat.*	*Cold stor*	*Amb.*	*LDPE pack.*	*Wax coat.*	*Cold stor.*	*Amb.*	*LDPE pack.*	*Wax coat.*	*Cold stor.*
Pu	0	13.0a	13.0a			8.6bc	8.6a			0.34a	0.34a		
	2	10.7b	11.8b			8.8ab	8.3bc			0.29ab	0.29b		
	4	9.9c	11.4b			9.2a	8.4ab			0.29ab	0.29bc		
	6	8.7d	11.3b			8.3c	8.2bc			0.29ab	0.29bc		
	8	7.2e	9.0c			7.9d	8.0cd			0.28b	0.27bc		
	10	5.8f	7.0d			7.1e	7.6de			0.26b	0.28bc		
	12	4.3g	6.6de			6.2f	7.3e			0.26b	0.27cd		
	14		5.6ef				6.2f				0.25d		
	16		5.2f				6.2f			0.06	0.22e		
	p	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000

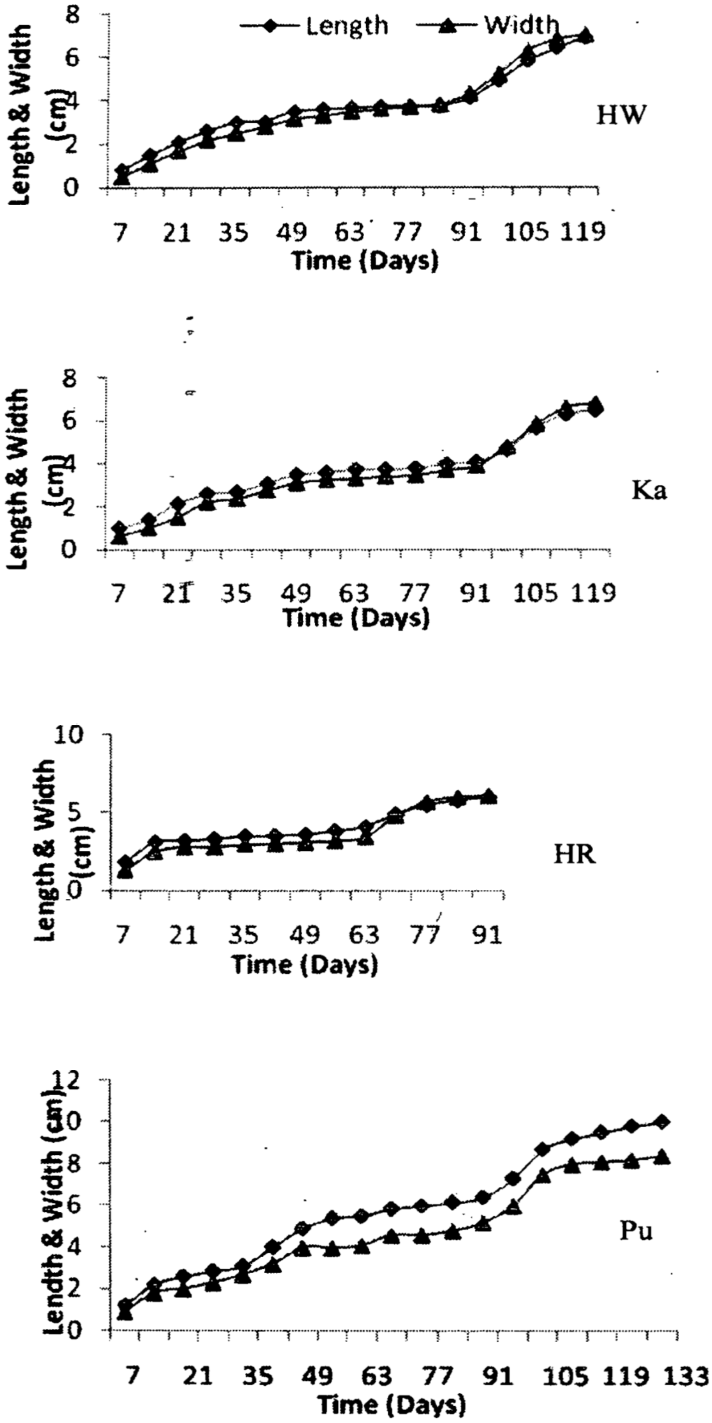

Figure 1. Fruit growth curves of four varieties of guava

Effect of pre-harvest chemical application on quality and shelf life of Horana White, Kanthi and Horana Red

The fruits treated with 4 % $Ca(NO_3)_2$ had significantly higher ($p<0.05$) shelf life followed by 2 and 1 % $Ca(NO_3)_2$ and the shelf life of untreated fruits were significantly low (p=<0.001; Figure 3). Firmness of the fruit is important in extending the shelf life and Ca plays a special role in maintaining the cell wall structure of fruits by interacting with pectic acid in the cell walls to form Ca pectate (Bakshi *et al.*, 2005 Poovaiah (1986) has studied the role of Ca in prolonging the storage life of fruits and vegetables and reported that it's positive effects on retaining fruit firmness.

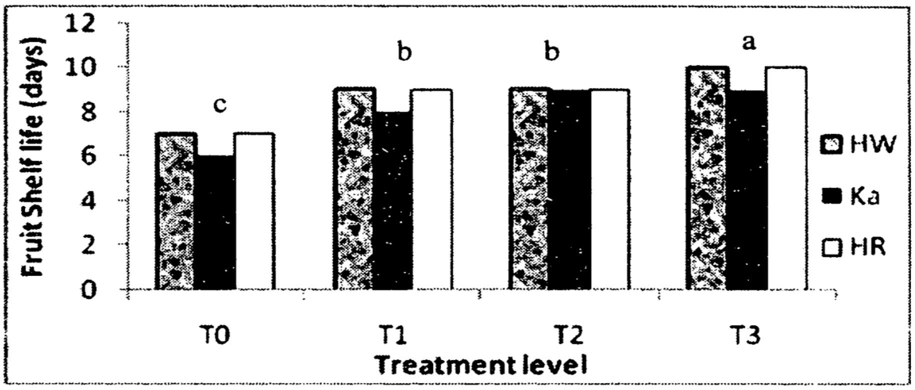

Figure 3. Shelf life of guava fruits at different levels of $Ca(NO_3)_2$

The effect of pre-harvest spraying of Ca on quality of guava fruits is shown in Table 4.

Fruit firmness was significantly reduced ($p<0.05$) from the harvested time (day 0) to the second day of storage, probably due to the conditions of fruit storage specially at ambient temperature. This reduction of firmness would be attenuated under refrigerated storage conditions. However, Ca-treated fruits showed a better firmness even at fully ripen stage thus making post-harvest handling easy. The differences in fruit firmness between the control and the Ca-treated fruits increased with the duration at storage, (Table 4). Thus, these effects of $Ca(NO_3)_2$ causing a greater fruit firmness can be explained by the role of Ca in the rigidity of rind tissues (Singh *et al.*, 1993; Conway *et al.*, 2002). Conway and Sams (1987) showed a remarkable decrease in the area of decay in apple fruits when treated with Ca. Application of lime to an acid Red Latasol before guava tree planting has provided greater firmness (Prado *et al.*, 2005). However, plant uptake of Ca can be affected by interactions with other soil elements, thus making soil application ineffective under some soil conditions.

Table 4. Changes in texture, TSS and TAA with the time in fruits treated with $Ca(NO_3)_2$

Days from har		Fruit firmness (Kg)				TSS (°B)				TAA (%)			
		T0	*T1*	*T2*	*T3*	*T0*	*T1*	*T2*	*T3*	*T0*	*T1*	*T2*	*T3*
HW	0	12.2a	12.7a	13.1a	13.4a	10.5b	10.7b	11.1a	11.5a	0.41a	0.39a	0.38a	0.37a
	2	8.8b	9.2b	9.6b	10.1b	11.3a	11.7a	11.3a	11.0b	0.38a	0.34b	0.35ab	0.36a
	5	4.4c	5.0c	5.7c	7.0c	9.3c	9.0c	9.0b	9.8c	0.29b	0.34b	0.33bc	0.34ab
	7	2.1d	4.1d	4.6d	6.3d	7.1d	7.1d	7.6c	8.0d	0.26b	0.31c	0.30c	0.31bc
	8		3.9d	4.5d	5.2e	6.9d	6.8d	7.0d	6.6e	0.20c	0.22d	0.23d	0.28c
	9		3.5d	4.1d	5.0e		6.1e	6.2e	6.3ef		0.20d	0.22d	0.22d
	10				5.0e				6.2f				0.20d
	p	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
	cv %	9.2	7.2	5.6	4.0	2.9	3.6	2.5	2.3	4.4	4.9	6.2	5.7
Ka	0	9.8a	10.0a	10.8a	11.1a	8.5b	8.7c	8.7c	9.0c	0.45a	0.44a	0.41a	0.42a
	2	7.6b	7.9b	7.9b	9.2b	10.4a	10.9a	10.8a	11.0a	0.43b	0.41b	0.39a	0.41b
	5	4.6c	5.6c	6.0c	6.7c	8.1c	9.2b	10.1b	10.1b	0.40c	0.36c	0.36b	0.35c
	6	3.0d	4.2d	4.7d	5.4d	7.6d	7.9d	8.5c	9.9b	0.33d	0.35d	0.32c	0.35c
	8		3.2e	3.6e	3.9e		7.2e	7.3c	8.8c		0.32e	0.31d	0.30d
	9				3.2f				8.2d				0.29d
	10												
	P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	cv %	4.9	4.0	2.4	3.2	2.1	1.7	2.3	2.7	2.3	1,.5	2.8	1.7
HR	0	12.3a	12.5a	12.6a	13.0a	8.6ab	8.7ab	8.8a	8.7a	0.55a	0.5a	0.51a	0.49a
	2	9.9b	10.2b	10.6b	10.9b	9.2a	9.0ab	9.2a	9.2a	0.49b	o.47b	0.49a	0.47ab
	5	6.2c	6.3c	6.8c	7.7c	8.3b	8.3b	7.8b	8.0b	0.41c	0.40c	0.45b	0.45b
	6	4.1d	4.4d	5.7d	6.1d	7.2c	7.2c	7.6b	7.7b	0.39c	0.37d	0.42bc	0.41c
	7	3.2e	4.2d	4.8e	4.7e			6.9c	6.8c			0.4c	0.39c
	8		4.2d	4.1f	3.1f			5.2d	6d			0.34d	0.34d
	10				3.0g				6d				0.32d
	p	0.000	0.000	0.000	0.000	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000
	cv %	2.6	2.5	3.9	3.1	3.6	3.2	3.9	4.5	4.5	1.6	4.2	3.0

The TSS content has increased and then reduced, while TAA has a gradual but a significant reduction ($p<0.05$) with storage period, irrespective of the Ca treatment and variety. This indicates that the normal ripening in Ca-treated fruits is similar to that of the untreated control.

CONCLUSIONS

Fruit maturity at harvest has an impact on quality and shelf life of guava. The colour turns from dark green to whitish green followed by yellowish green and yellow during ripening. The whitish green stage provides an adequate hard texture, optimum TSS and TAA, and thus can be identified as the commercial maturity stage.

The storage environment has an impact on shelf life of guava fruits. Fruits stored at refrigerated temperature resulted in a more controlled and gradual ripening than those stored at ambient temperature. The LDPE packaging and wax coating at ambient temperature resulted in an extended shelf life of guava fruits. The LDPE packaging was successful in var. Pubudu with acceptable flavor and texture. The gauava var Pubudu had a longest shelf life followed by Horana White, Kanthi and Horana Red.

Fruits showed a double-sigmoid growth pattern and time taken for exponential growth phase was determined, during which chemicals to be applied. Fruit shelf life of Ca-treated guava was higher to that of the untreated control and had a better firmness. The beneficial effects of Ca treatment increased with the duration of storage. The Ca treatment did not have a singificant effect on normal ripening of the tested guava varieties.

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