CARIBBEAN FOOD CROPS SOCIETY

37

Thirty Seventh Annual Meeting 2001

Trinidad and Tobago

Vol. XXXVII

Proceedings of the Caribbean Food Crops Society. 37:233-242. 2001

OCCURRENCE OF THE CLIMACTERIC PATTERN OF RESPIRATION IN MINIATURE GOLDEN APPLE (*SPONDIAS CYTHEREA*) FRUIT

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ABSTRACT: Miniature golden apple fruit (*Spondias cytherea*) were harvested at three stages of maturity (immature, mature-green and breaker stages) and stored at 9°C, 21°C and 31°C for up to 14 days. Throughout storage, fruit were evaluated for carbon dioxide (CO_2) and ethylene (C_2H_4) production rates. For fruit at all three maturity stages stored at 9°C, respiration rates remained very low throughout storage increasing rapidly beyond 12 days at which time both senescence and chilling injury symptoms were well established. For fruit stored at 21°C and 31°C, respiration rates increased over time with senescence occurring in immature fruit and ripening occurring in mature-green and turning fruit. Ethylene was only detected at 21°C and 31°C and increased over time in fruit at all maturity stages. The respiratory pattern of the miniature golden apple was typical of a climacteric fruit. In immature fruit the rise in the rate of ethylene production occurred beyond 4 days and coincided with the climacteric rise of respiration and external evidence of senescence. In mature-green and turning fruit the rise in the rate of ethylene production occurred beyond days 5 and 4 respectively and also coincided with increased respiration rates.

INTRODUCTION

The golden apple *Spondias cytherea* is a member of the Anacardiaceae family and is native to the Society Islands of the South Pacific, Melanesia and Polynesia. Common names include the golden apple, jew plum, june plum, pommecythere and ambarella (Winsborrow, 1994). Golden apples are found as the common large fruit type where the tree attains a height of 9-25 m, and the miniature fruit type, where trees attain 1.5 - 3 m in height. Fruit of both types are oval, round or pear-shaped. Fruit size varies from about 5 to 6 cm in diameter and 9 to 10 cm in length with an average weight of 200 grams for the large fruit while miniature fruit are about 3 to 4 cm in diameter and 5 to 6 cm in length with an average weight of 65 grams (Persad, 1996; Winsborrow, 1994).

Early bearing, year round availability, ease of harvesting and the reduced likelihood of mechanical damage when harvesting is done at a more advanced stage are some of the characteristics of the miniature golden apple that give it a distinct advantage over the large type. Both fruit types have potential for increased utilization in fresh and processed forms. However, while the large fruit is well utilized locally and even exported by Grenada and to a lesser extent St. Vincent, the miniature fruit remain underexploited. As is the case with many tropical fruits, the availability of fresh miniature golden apple fruits is limited by a short post-harvest shelf-life. In the tropics fruits generally ripen and decay very quickly under ambient conditions, hence miniature golden apples ripen fully under ambient conditions however, deterioration in quality proceeds quickly due to its own innate physiological processes.

Symptoms of quality deterioration include excessive softening and fresh weight loss, the development of external and internal discolourations as well as unacceptable organoleptic attributes, and the onset of pathological decay.

Harvested fruits are living organs and as such they continue to respire and lose water just as before they were harvested. However, such losses are not replaced in a postharvest environment. Internal changes occur in stored fruits which directly affects postharvest quality and these include biochemical changes, as well as changes in texture and in respiration rates among others. It is not possible to improve the quality of produce after harvest but it is possible to reduce the rate of the development of undesirable changes such as loss of cellular integrity, excessive softening, the development of off-flavours and odours which results from senescence and decay. Temperature is the most important environmental factor influencing the deterioration of harvested fruits (Kader, 1992). Most perishable horticultural commodities store longer at temperatures just above 10^0C while at temperatures above the optimum, the rate of deterioration increases twofold to fourfold for every 10^0C rise in temperature (Kader, 1992).

Understanding some of the major physiological processes within harvested fruits, that affect quality, is essential if fruits are to be stored successfully for extended periods. The maintenance of optimum postharvest quality in fruits is dependent on the extent to which shelf-life can be extended by controlling the rates of respiration and ripening, the effects of moisture loss and ethylene production.

Published studies on the large golden apple fruit include those reported by Dualmerie (1994) and Mohammed and Wickham (1996), but there are no published data for the miniature fruit. Accordingly, this study was undertaken to determine respiration and ethylene production rates, chilling sensitivity and organoleptic changes in miniature golden apples during storage.

MATERIALS AND METHODS

Miniature golden apple fruit were hand-harvested from a small orchard in East Trinidad during 1997. Fruit were graded into immature (M1), mature-green (M2) and slightly turning or breaker (M3) according to size and colour. Fruit were placed in single-ply cardboard boxes and transported to the laboratory in the Department of Food Production at the University of the West Indies, St. Augustine within one hour of harvest. Fruit were washed in tap water, then dipped for 3 minutes in 300μg/ml, sodium hypochlorite solution to control surface pathogens and left for 25 minutes in a holding room (21^0C, 73% R.H.) until surface moisture had evaporated. Fruit of all maturity stages were then stored at 9^0C, 21^0C and 31^0C.

Chilling injury, respiratory measurements and ethylene production rates were taken at harvest, then daily while sensory evaluations were done at harvest followed by 2 day storage intervals up to 14 days. Bioelectrical resistance and electrolyte leakage measurements were taken at harvest, followed by 3 day storage intervals up to 12 days.

Fruit respiration was determined by the use of a Finnigan gas chromatograph Model # 9001; (Austin, Texas) which was used to measure simultaneous carbon dioxide (CO_2) and ethylene (C_2H_4) production rates daily. Ethylene was measured using a Flame ionization detector (FID) while carbon dioxide was measured using a Thermal conductivity detector (TCD). Fruit were weighed and incubated in 1-litre air-tight jars for 2 hours. Approximately 0.3 ml of the atmosphere in the jars was withdrawn with a 1.0 ml syringe and injected through a rubber septum in the gas chromatograph with helium as the carrier gas with a flow rate of 25 ml/min. The flow rates of hydrogen and air were 15 ml/min and 175 ml/min respectively. A megabore column of 0.53 mm and 30 m in length were used. The levels of both CO_2 and C_2H_4 were measured and calculated against standard gas mixtures. The lowest concentration or rate of carbon dioxide production that could be detected was 0.01% whereas that of ethylene was 1μg/ml.

Chilling injury (CI) based on external damage was scored on each fruit using a subjective scale: 1 = no damage, 2 = slight damage, 3 = medium damage, 4 = severe damage, 5 = very severe damage. The CI index was calculated according to the formula used by Pesis *et al.,* (1994).

$$\text{CI Index} = \frac{\sum_{0}^{5} (\text{injury level}) \times (\text{number of fruit at this level})}{\text{total number of fruit}}$$

Bioelectrical resistance (BER) was determined with an Osmose resistance meter (OZ-86 Shigometer) (Lougheed *et al.*, 1981). Electrolyte leakage (EL) was measured using a Fisher Conductivity Meter (Model 152, Pittsburg, N.J.) and was determined using three 4 mm x 9 mm width disks weighing a total of 1 gram which were first washed in 20 ml of de-ionized water then shaken at 200 cycles per minute in 30 ml of 0.3M mannitol, as described by Cabrera and Saltveit (1990) using a Lab-line Orbit environ-shaker (Model 3528-5, Melrose Park, IL.) and was expressed as a percentage of the total conductivity after boiling.

Marketable quality was rated for each fruit using the following subjective scale 1= very poor quality, 2= poor quality, 3= moderate quality, 4= good quality and 5= excellent. The number of fruit with a rating of 3 and above were used to calculate percentage marketable fruit.

Comparative sensory evaluations for texture, aroma and flavour were performed using a 20 member semi-trained panel. Panelists used a modified hedonic scale of 1-5 with 1 representing unacceptable, 2-slightly acceptable, 3-acceptable (limit), 4-very acceptable and 5 extremely acceptable (Ranganna, 1986).

Severity of decay was rated on each fruit using the following subjective scale 1=no decay, 2=slight, 3=moderate, 4=severe and 5=complete breakdown. The incidence was reported as the percentage of fruit exhibiting a severity rating >1. To determine the major pathogen responsible for decay, samples from the advancing edge of the lesion were removed and cultured in a sterile environment on potato dextrose (PDA) agar plates. Subculturing was done on cornmeal agar until a pure culture with three isolated colonies were obtained. Pathogens associated with decayed fruit were identified by examination of the fruiting bodies under the light microscope (Brathwaite, 1981).

This experiment consisted of a completely randomized design with a factorial arrangement of variables. Each treatment was replicated three times with each replicate consisting of 10 fruit. Data were subjected to Analysis of Variance, using GENSTAT (Genstat 5.0, 1995) and the levels of significance determined by the F-test. Comparison of the means using the least significant difference (LSD) method was done at the 5% level, where applicable, in addition to the determination of correlation coefficients using MINITAB (Minitab Inc.,1991).

RESULTS AND DISCUSSION

Percentage marketable fruit

The quality of miniature golden apple fruit deteriorated over time ($P<0.001$) irrespective of storage temperature, resulting in declines in percentage marketable fruit (Figures 1A-C). Quality deterioration in fruit was generally evidenced by increased respiration and ethylene production rates as well as decay, tissue browning and degreening. Deterioration was more rapid in less mature fruit during storage at 9°C and 21°C but there was no influence of maturity on shelf life for fruit stored at 31°C as deterioration was extremely rapid for all stages of maturity (Figure 1C). At 21°C mature green and turning fruit storing relatively well for up to 8 days whereas at 9°C, fruit marketability was limited by the development of chilling injury with time (Figure 1A).

Respiration (CO_2) and ethylene (C_2H_4) production rates

Respiration rates remained very low in fruit of all maturity stages stored at 9°C for 12 days, beyond which major increases occurred. By this time both senescence and chilling injury symptoms were well established (Figure 1D). At 21°C and 31°C, respiration rates increased over time, typical of a climacteric fruit, with ripening occurring in mature-green and turning fruit and the attainment of climacteric peaks within 3-6 days (Figures 1E-F). Increases in respiration rates in immature fruit were attributed to senescence.

Ethylene was only detected at 21°C and 31°C and increased over time in fruit at all maturity stages (Figures 2A-B & Table 1). In immature fruit the rise in the rate of ethylene production occurred beyond 4 days and coincided with an elevated respiration rate and external evidence of senescence. In mature-green and turning fruit the rise in the rate of ethylene production occurred beyond days 5 and 4 respectively and coincided with increased respiration rates (Figures 1E-F and 2A-B).

Chilling injury index, bioelectrical resistance and electrolyte leakage

Fruit stored at 9°C developed chilling injury over time, but, while immature fruit had very severe injury beyond 10 days and mature-green fruit had moderate injury, turning fruit had only slight chilling injury (Figure 3). Chilling injury was evidenced by skin pitting (CI index), elevated respiration rates and electrolyte leakage (EL), as well as reduced bioelectrical resistance (BER). Immature fruit stored at 9°C had evidence of slight chilling injury from day 4 and symptoms became very severe one week later. Severe chilling injury damage was evidenced by extensive skin pitting accompanied by fruit showing the highest respiration rates beyond day 12 and the highest EL during storage and generally lower BER compared to turning fruit throughout (Tables 1 & 2). Both objective measurements BER and EL are commonly used as indicators of losses in membrane integrity in chilled-stressed tissues in many fruit.

Lougheed *et al.* (1981) and Mohammed and Wickham (1996) reported a similar inverse relationship between EL and BER, with the latter observing the same in golden apple fruit of the large type. An inverse relationship ($P<0.05$) was found to exist between BER and EL in immature fruit with $r = -0.469$. The equation which best described the relationship was $y = 4.44 + 1.29x$. Pitting of the skin in miniature golden apples was similar to that described by Abe *et al.* (1974) in eggplant which was attributed to the collapse of cells located several layers beneath the fruit surface.

Sensory evaluation (flavour, aroma and texture)

The production of aroma volatiles was greater in turning fruit than mature-green fruit at the two higher temperatures (Tables 2 & 3). At all three storage temperatures, turning fruit received the highest texture ratings throughout this study. Mature-green fruit received higher ratings than immature fruit up to 4 days at 21°C and 31°C and beyond 6 days at 9°C. Acceptable ratings for flavour were only given to mature-green and turning fruit (Tables 2 & 3). Mature-green and turning fruit at 21°C and 31°C were given acceptable organoleptic ratings for flavourdue to occurrence of ripening and accompanying changes those fruit ripening. At 9°C mature-green and turning fruit also received acceptable flavour ratings and this could be attributed to their advanced stage of maturation.

Decay

Decay only occurred in fruit stored at 21°C and 31°C after about 7 days resulting in termination of storage after 8 days (Table 4). The major fungus responsible for fruit decay was of the *Asteromella* spp.

CONCLUSION

Based on this study, it was concluded that the miniature golden apple is a climacteric fruit with simultaneous increases in CO_2 and C_2H_4 production rates occurring during storage at 21°C and 31°C. Also as is quite common for many tropical fruit, this fruit was found to be highly susceptible to chilling injury during storage at 9°C, however, injury was less severe in fruit of greater maturity.

ACKNOWLEDGEMENTS

The authors are grateful to the Campus Committee for Graduate Studies and Research of the University of the West Indies (St. Augustine) for providing the funding for this study. Special mention must also be made of several individuals whose assistance made this study possible namely Mr. Bruce Lauckner, Statistician at CARDI U.W.I. Campus St. Augustine, and Mr. K. John and S. Ali, Laboratory Technicians, for their invaluable assistance.

REFERENCES

Abe, K., Iwata, T, and Ogata, K. (1974) Ultrastructural changes during chilling stress. Journal of Japan Society of Horticultural Science. 42:72-82.

Brathwaite, C.W.D., (1981) In: Lewis, E. (Ed), Introduction to the diagnosis of plant diseases. San Jose, Inter-American Institute For Cooperation On Agriculture, pp. 1-37.

Cabrera, R.M. and Saltveit, M.E., (1990) Physiological response to chilling temperatures of intermittently warmed cucumber fruit. J. Am. Soci. Hort. Sci. 117, 314-335.

Daulmerie, S., (1994) Post-harvest technology of golden apples. In: Proceedings of the Third Regional IICA Workshop on Tropical Fruit, 16-20 May 1994, Grenada, pp. 168-171.

Kader, A. (1992) Postharvest technology of horticultural crops. University of California Division of Agriculture and Natural Resources. Publication 3311.

Lougheed, E.C., Miller, S.R., Ripley, B.D. and Cline, R.A., (1981) Electrical impedance of daminozide and calcium-treated McIntosh apples. Experimentia. 37, 835-836.

Mohammed, M. and Wickham, L.D., (1996) Occurrence of chilling injury in golden apple (*Spondias dulcis*, Sonn.) fruit. J. Food Qual. 20, 91-104.

Persad, C. (1996) Production and marketing of golden apples. In Proceedings of theWorkshop on Marketability of Caribbean Minor Fruit. 19-24 October, 1996. Edited by St. Clair Forde. 89-97. Port of Spain, Trinidad: CARDI/CTA.

Pesis, E., Marinansky, R., Zauberman, G. and Fuchs, Y., (1994) Prestorage low-oxygen atmosphere treatment reduces chilling injury symptoms in 'Fuerte' avocado fruit. HortScience 29, 1042-1046.

Ranganna, S., (1986) Sensory evaluation. In: Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw-Hill Publishing Company Ltd, New Delhi, pp. 595-645.

Winsborrow, C., (1994) Golden apple production. In: Proceedings of the Third Regional IICA Workshop on Tropical Fruit, 16-20 May1994, Grenada, pp. 178-181.

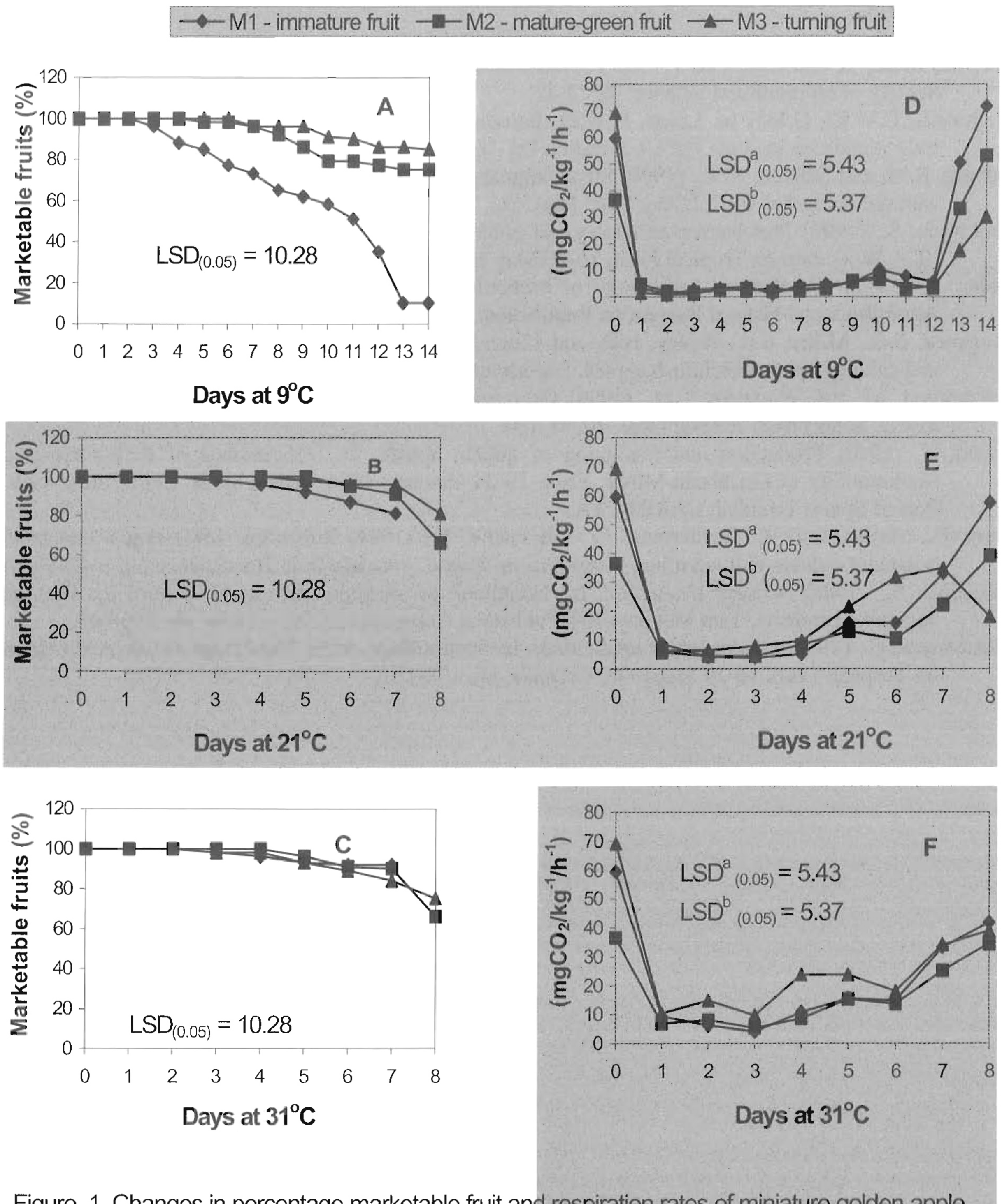

Figure. 1. Changes in percentage marketable fruit and respiration rates of miniature golden apple fruit at different storage temperatures and durations LSD: over time[a] while across maturity stages and temperature on the same day[b]. Level of significance (P<0.001).

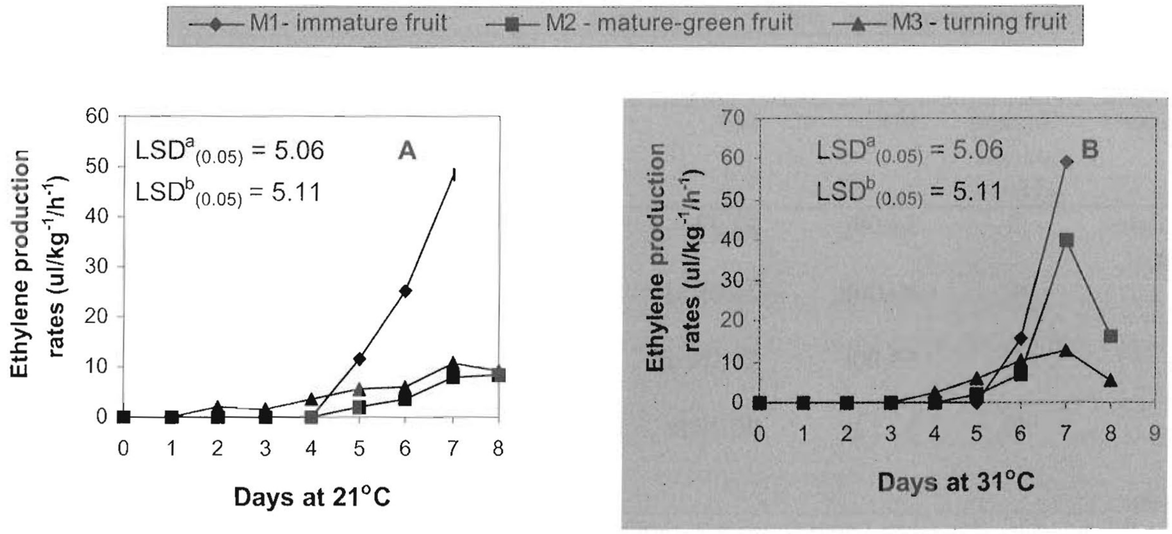

Figure 2. Changes in ethylene production rates in miniature golden apple fruit after 8 days of storage at 21°C and 31°C. LSD:over time[a] while across maturity stages and temperatures on the same day [b]. Level of significance (P<0.001).

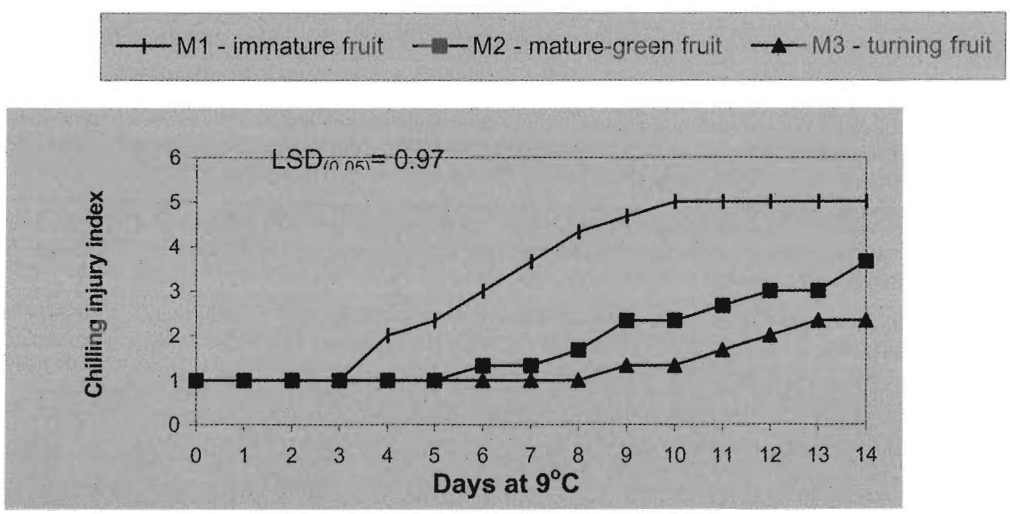

Figure. 3. Interaction effects of storage duration x temperature x maturity on the chilling injury index of miniature golden apple fruit stored for 14 days. Level of significance was (P<0.001).

Table 1. Interaction effects of storage period x temperature x maturity on electrolyte leakage in miniture golden apples during storage at 9C and 21C for 12 days.

		Temperature					
		9C			21C		
Parameter	Storage period (Days)	M1	M2	M3	M1	M2	M3
Electrolyte leakage)	3	34.00g [y]	22.32c	17.28b	10.00a	23.92cd	29.76ef
	6	48.00h	24.08cd	17.60b	10.08a	74.08k	90.88l
	9	55.00i	26.16cde	27.84de	ND[x]	ND	ND
	12	67.12j	27.28de	33.00fg	ND	ND	ND
$LSD_{(0.05)}$				4.17			

[y] Means followed by the same letter(s) are not significantly different ($P<0.05$), [x] ND=no data, due to fruit decay. Prestorage electrolyte leakage M1=11.47, M2=20.67, M3=17.03. M1 (immature fruit, M2 (mature-green fruit), M3 (turning fruit).

Table 2. Main effects of storage duration, temperature, and fruit maturity on the bioelectrical resistance and flavour of stored minitature golden apple fruit.

Treatments	Bioelectrical resistance (kilohms)[x]	Flavour
Days (D)		
0	58.08b[y]	1.00a
1		
2		1.96b
3	63.92b	
4		2.00b
5		
6	58.00b	2.33b
7		
8		2.81b
9	45.25a	
10		2.33b
11		
12	39.00a	2.11b
13		
14		2.11b
15		
LSD $_{(0.05)}$	10.56	0.49
Temperature C (T)		
8-10 T1	55.50a[y]	2.08a
20-22 T2	58.72a	2.42a
30-32 T3	-	2.28a
LSD $_{(0.05)}$	4.02	0.39
Maturity (M)		
Immature M1	47.03a[y]	1.02a
Mature-green M2	48.57a	1.81b
Turning M3	58.75b	3.46c
LSD $_{(0.05)}$	5.98	0.58
Statistical significance		
Day (D)	*	*
Temperature (T)	NS	NS
Maturity (M)	*	**
D x T	NS	*
D x M	NS	**
T x M	NS	NS
D x T x M	NS	*

[y] Means followed by the same letter(s) are not significantly different ($P<0.05$), [x]ND no data due to fruit decay. Prestorage electrolyte leakage M1=11.47, M2=20.67, M3=17.03. M1 (immature fruit, M2 (mature-green fruit), M3 (turning fruit). [x] Measurements only taken on days 0, 3, 6, 9, and 12.

Table 3. Interaction effects of storage duration x temperature x maturity on the texture and aroma of miniature golden apples stored for 14 days.

		9C			21C			31C		
Parameters	Storage Duration (Days)	M1	M2	M3	M1	M2	M3	M1	M2	M3
Texture	2	1.00a [y]	2.33d	3.33ef	1.33ab	2.33c	3.00de	1.00a	2.33c	3.67fg
	4	1.00a	1.33ab	3.33ef	1.33ab	2.33c	3.67fg	1.00a	1.33ab	4.00gh
	6	1.00a	1.00a	4.00gh	1.00a	3.00de	3.33ef	1.00a	3.33ef	4.33h
	8	1.00a	1.67b	4.33h	ND[x]	3.00de	4.00i	ND	3.00de	3.33ef
	10	1.00a	2.67ed	4.33h	ND	ND	ND	ND	ND	ND
	12	1.00a	3.33ef	4.00gh	ND	ND	ND	ND	ND	ND
	14	1.00a	3.00de	3.67fg	ND	ND	ND	ND	ND	ND
LSD $_{(0.05)}$						0.48				
Aroma	2	1.00a	1.00a	2.00b	1.00a	1.00a	2.33c	1.00a	1.00a	2.67d
	4	1.00a	1.00a	2.00b	1.00a	1.00a	3.00d	1.00a	1.00a	2.00b
	6	1.00a	1.00a	2.00b	1.00a	3.33f	3.67g	1.00a	2.00b	3.00e
	8	1.00a	1.00a	2.00b	ND	3.00d	3.67g	ND	3.00e	4.00h
	10	1.00a	1.00a	2.00b	ND	ND	ND	ND	ND	ND
	12	1.00a	1.00a	2.00b	ND	ND	ND	ND	ND	ND
	14	1.00a	1.00a	2.00b	ND	ND	ND	ND	ND	ND
LSD $_{(0.05)}$						0.25				

[y] Means followed by the same letter(s) are not significantly different ($P<0.05$), [x]ND no data due to fruit decay.