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Effects of Cultivars, Growing and Storage Environments on Quality of Tomato

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***Abstract*—**The postharvest quality management of tomatoes is important to limit the amount of losses that occur due to deterioration between harvest and consumption. This study was undertaken to investigate the effects of pre- and postharvest integrated agro-technologies, involving greenhouse microclimate and postharvest storage conditions, on the postharvest quality attributes of four tomato cultivars. Tomato fruit firmness, colour (hue angle (h°) and L* value), pH and total soluble solids for the cultivars Bona, Star 9037, Star 9009 and Zeal, grown in a fan-pad evaporatively-cooled and an open-ended naturally-ventilated tunnel, were harvested at the mature-green stage. The tomatoes were stored for 28 days under cold storage conditions, with a temperature of 13°C and RH of 85%, and under ambient air conditions, with a temperature of 23± 2°C and RH of 52± 4%. This study has provided information on the effect of integrated pre-harvest and postharvest agro-technologies, involving greenhouse microclimate and postharvest storage environment on the postharvest quality attributes of four of the tomato cultivars in South Africa. NVT-grown tomatoes retained better textural qualities, but ripened faster by changing from green to red faster, although these were reduced under cold storage conditions. FPVT-grown tomatoes had lower firmness, but ripened slowly with higher colour attributes. With cold storage conditions, the firmness of FPVT-grown tomatoes was maintained. Cultivar Bona firmness and colour qualities depreciated the fastest, but it had higher TSS content and lower pH values. Star 9009 and Star 9037 presented better quality, by retaining higher firmness and ripening slowly, but they had the lowest TSS contents and high pH values, especially Star 9037. Cold storage improved the firmness of tomato cultivars with poor textural quality and faster colour changes.

***Keywords*—**Greenhouse, micro-climate, tomato, postharvest quality, storage.

I. Introduction

TOMATOES are the second most important vegetable crop in South Africa, contributing about 24% of the country's vegetable production [1]. Most of the tomato production in South Africa's is carried out in open fields, although protected cultivation is gaining popularity. Protected environment cultivation is mostly carried out in naturally-ventilated tunnels, although the use of the fan-pad evaporatively cooled facilities is gaining popularity [2]. Fan-pad evaporative cooling technology is costly to install, operate and maintain and a constant and reliable supply of electricity and good quality water are required. Naturally-ventilated facilities are less expensive, but there is limited control of the microclimate. The effect that the microclimate in these facilities has on the postharvest quality of tomatoes under South African conditions is limited. In addition, a substantial number of new tomato cultivars are released on to the South African markets every year. The selection of which cultivar to use is primarily based on information provided by the seed companies [2]. Failure to select the correct cultivar for a particular production method can lead to the production of an inferior quality product [3] and may lead to rejection by consumers [4]. This study was undertaken to establish the influence of two different greenhouse microclimates, the cultivar, storage conditions and time on the effect of postharvest quality attributes of fresh market tomatoes available on the South African market.

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II. Materials and Methods

A. Sample Preparation

Four fresh market tomato cultivars (Bona, Star 9037, Star 9009 and Zeal) were grown in two polyethylene covered tunnels at the Ukulinga Research Farm of the University of KwaZulu-Natal, Pietermaritzburg, South Africa (29.67°S and 30.40° E, 840 m above sea level), during summer, from October 2012 to January 2013. One tunnel was a fan-pad evaporatively cooled tunnel (FPVT), while the other was an open-ended naturally-ventilated tunnel (NVT), with the open ends covered with black and white Knittex® 40 insect screen netting. The air temperature and relative humidity (RH) inside both tunnels were monitored throughout the growing season, using Hobo® Pro v2 optic data loggers (Onset Computer Corporation, Bourne, USA), equipped with temperature and relative humidity sensors (Table I). Seven-week old seedlings, bought from a local nursery, were transplanted into 10 L black plastic bags on the 26th September 2012. The tomatoes were drip-irrigated and fertilizers were applied through the irrigation water.

Forty randomly-selected fruits per cultivar from each greenhouse (320 fruits in total) were harvested at the mature-green stage. For each cultivar, half of the fruits (20 fruits) were stored under cold storage conditions and the other half under ambient conditions. The fruits were first cleaned, by washing them with tap water, and then stored in clear plastic bags. A climate test chamber (CTS-GmbH®, Hechingen, Germany) was used for cold storage. Under ambient air storage, the temperature was 23± 2°C and the RH was 52± 4%. In the controlled storage chamber, the temperature was set at 13°C with a RH of 85%.

TABLE I
THE MAXIMUM, MINIMUM AND MEAN TEMPERATURES AND RELATIVE HUMIDITY IN THE NATURALLY-VENTILATED (NV) AND THE FAN-PAD EVAPORATIVELY COOLED (FPV) TUNNELS

Time (Months)	Micro-climate	T_{max} (±SD)	T_{mean} (±SD)	T_{min}(± SD)	$RH_{maximum}$ (±SD)	RH_{mean} (±SD)	$RH_{minimum}$ (±SD)
Oct	NV	29.9 ±4.8	18.9±2 .2	13.3 ±0.9	96.0 ±1.5	79.3±5. 9	47.6 ±10.3
	FPV	29.2 ±2.9	19.2 ±1.5	14.0 ±0.8	97.3 ±0.9	83.5 ±4.6	53.7 ±8.8
Nov	NV	29.4 ±3.8	19.6 ±2.0	14.2 ±1.2	96.7 ±1.4	80.3 ±5.3	50.7 ±9.3
	FPV	30.9 ±2.3	20.9 ±1.4	14.8 ±1.2	98.7 ±0.5	83.9 ±4.2	56.8 ±8.7
Dec	NV	33.8 ±2.8	22.9 ±1.5	16.7 ±1.0	97.1 ±0.7	78.6 ±3.3	45.6 ±6.1
	FPV	29.0 ±1.4	22.1 ±0.7	17.0 ±0.7	99.1 ±0.2	83.9 ±2.0	57.6 ±4.0
Jan	NV	33.8 ±3.9	23.0 ±1.8	17.0 ±0.8	96.9 ±0.9	78.6 ±5.0	46.5 ±8.6
	FPV	29.3 ±2.0	22.0 ±1.1	17.6 ±0.8	99.5 ±0.1	88.0 ±3.1	64.8 ±6.3

± indicates 99% confidence. T = temperature; RH = relative humidity

B. Quality Attributes

The individual tomatoes were assessed for firmness, colour, total soluble solids (TSS) and pH on days 0, 7, 14, 21 and 28 of storage. The colour indicators were determined, using the Hunterlab Colourflex® EZ (Hunter Associates Laboratory, Inc., USA) spectrophotometer. Each fruit was measured for L*, a* and b* at three equatorial positions (blossom end, stem-end and mid-way), which were averaged to determine the overall values for L*, a* and b* [6]. Using a* and b*, the hue angle (h) for each fruit was calculate. The tomato firmness was determined by the puncture test, using the Instron® 3345 Universal Testing Machine (Instron, UK) with a 5 kN capacity. Each fruit was placed in the holding part of the machine, and then a 2 mm stainless steel probe, attached to a loading cell, was driven into the fruit at a penetration rate of 10 mm.minute-1. The peak force required to penetrate the fruit, known as the rupture point, was measured at three equatorial positions (blossom-end, stem-end and mid-way) on the fruit. For the pH and the TSS, each tomato fruit was homogenised into a pulp, using a hand-held processor. The pH was then determined, using a Crison® Micro-pH 2000 (Crison Instruments, S.A., Barcelona, Spain) pH meter with a sensitivity of ±0.01. The TSS was determined, using a digital Palette® PR101 (Atago Co. Ltd. Japan) hand-held refractometer, measuring from 0.0 to 45°Brix, with a measuring accuracy of °Brix ±0.2°, after calibrating it with distilled water.

C. Data Analysis

Data analysis was performed through the analysis of variance (ANOVA), using the MSTAT-C statistical and data management package with evaluations based on a P=0.05 significance level. The treatments mean separation was by least significant difference (LSD) using the Duncan's Multiple Range Test.

III. RESULTS

A. Firmness

Tomato fruit texture is a physical characteristic that describes the deformation of the tomato under the application of a force [5]. The effects of the microclimate conditions, cultivar differences, storage conditions and storage time on the firmness of the tomatoes were significant ($P<0.05$). The tomatoes grown in the NVT were 7.4% more resistant to puncture, with 4.16 N, than those grown in the FPVT, with 3.85 N. A lower firmness indicates a weaker skin, which is often associated with ripe, soft and mealy fruit [6]. Comparison of the firmness between the cultivars showed that the overall average firmness for Star 9009 was 21.5% higher, with 4.50 N, than that of Bona, which had an overall average of 3.53 N, but slightly different to Star 9037 and Zeal, which had overall averages of 4.15 N and 3.84 N, respectively. The overall average showed that the tomatoes stored under cold storage conditions, were 13.6% more resistant to puncture than those kept under ambient air conditions. Furthermore, under cold storage, a firmness texture was maintained for a longer time than under ambient storage.

There were significant ($P<0.05$) effects due to the interaction of microclimate × cultivar, cultivar × storage condition, cultivar × storage time and storage condition × storage time. Under both NVT and FPVT microclimates, Bona had the lowest overall average firmness, followed by Zeal. Under the NVT microclimate, Star 9009 was significantly firmer (22.7%) than both Bona and Zeal, but not significantly different from Star 9037, while Bona, Star 9037 and Zeal did not differ significantly. In the FPVT, the firmness of the four cultivars did not vary significantly from each other. Similarly, the firmness of fruits grown in the NVT did not vary significantly, when compared to those of the same cultivars from the FPVT.

Under cold storage conditions, cultivar Bona was significantly more resistant (24.1% firmer) to puncture than Bona kept under ambient storage conditions. The firmness for the other cultivars (Star 9037, Star 9009 and Zeal) were not significantly ($P>0.05$) influenced by storage conditions. Under ambient storage, Bona was significantly less firm (22.9% and 29.4%) than the overall average firmness of Star 9037 and Star 9009, respectively. In cold storage, the firmness of the cultivars did not vary significantly. Cultivar Bona resistance to puncture decreased significantly with storage time, especially between Days 14 and 21, when compared to the other cultivars (Fig. 1). The firmness of Star 9037, Star 9009 and Zeal decreased significantly during the first seven days and were constant over the next 14 days until Day 21, with slight differences between the cultivars. Tomatoes in cold storage maintained higher firmness over the storage period than ambient air stored tomatoes. There were no significant ($P>0.05$) influences on the firmness of the tomatoes, due to the interaction of microclimate × storage condition and the microclimate × storage time.

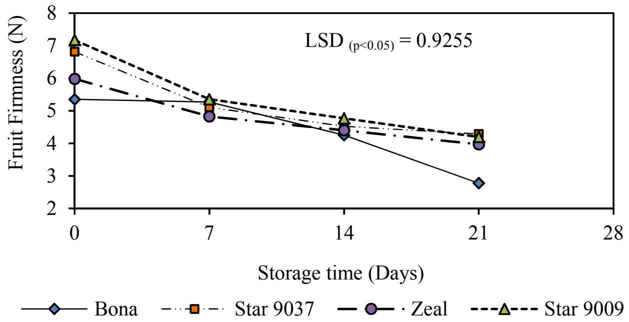

Fig. 1 The interaction effect of cultivar × storage period on the firmness of tomatoes over a 28-day storage period

The interaction of microclimate, cultivar and storage conditions had a significant ($P<0.01$) influence on the firmness of Bona and Zeal (Table II). Bona grown under NVT microclimate conditions and stored under ambient air conditions was 14.9% less resistant to puncture than Bona from the NVT and stored in cold storage. Similarly, NVT Zeal stored under ambient air conditions was 22.7% less resistant to puncture than NVT Zeal in cold storage, particularly between Days seven and 21. FPVT Bona stored at ambient air was 33.9% less firm, when compared to FPVT Bona in cold storage. There were no significant influences on Star 9037 and Star 9009.

Fig. 2 shows the interaction of microclimate × cultivar × storage time. The firmness of Bona grown in the FPVT decreased faster, in comparison to the other cultivars, starting from Day seven. The firmness of the other cultivars decreased significantly during the first seven days, after which the firmness became constant over the next 14 days. By Day 28, all the cultivars had decayed to such a level that performing the puncture test was impossible.

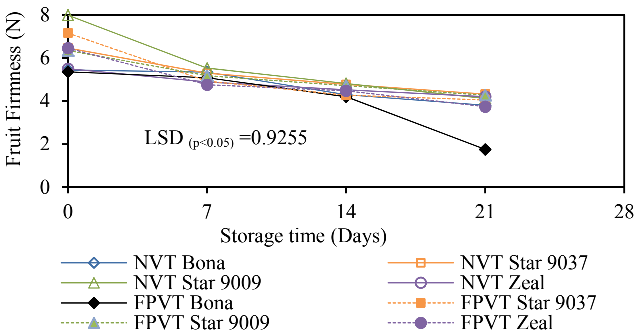

Fig. 2 The interaction effect of microclimate × cultivar × storage time on the firmness of tomatoes over a 28-day storage period. NVT = natural ventilated tunnel; FPVT = fan-pad evaporatively cooled tunnel

Fig. 3 shows the interaction of microclimate × storage condition × storage time over 28 days of postharvest storage. The firmness of tomatoes harvested from the FPVT and NVT and stored under ambient air conditions decreased rapidly, when compared to those grown in the FPVT and NVT and stored under cold storage conditions. Under cold storage conditions, the firmness of the NVT-grown tomatoes was significantly higher than that of those grown in the FPVT, during the first 14 days, with no significant difference between Days 14 and 21.

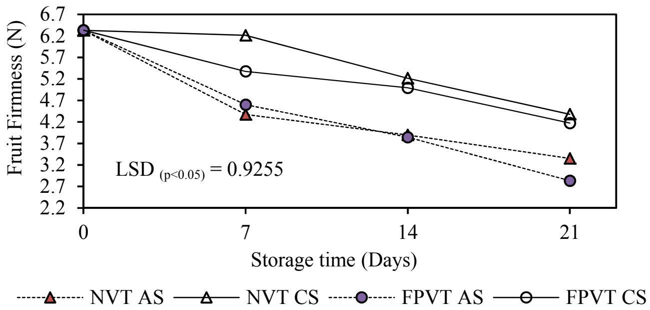

Fig. 3 The interaction effect of microclimate × storage condition × storage time on the firmness of the tomatoes. NVT = natural ventilated tunnel; FPVT = fan-pad evaporatively cooled tunnel; AC = ambient air storage; CS = cold storage

The interaction between cultivar × storage condition × storage time had a significant ($P<0.01$) effect on the firmness of all the cultivars (Fig. 4). The firmness of cultivar Bona, stored under ambient air conditions, decreased more rapidly, almost linearly, throughout the storage period. Similarly, the firmness of Star 9009 stored under ambient air conditions decreased the most during the first seven days in storage and then was constant between Days seven and 21. Under cold storage conditions, Star 9009 had the highest the firmness, especially during the first 14 days of storage.

B. Change in Colour

In addition to textural and firmness, colour is the most obvious post-harvest quality attribute used by consumers to gauge the ripeness and readiness for consumption of the tomato fruits [7] and [8]. The changes in the colour of tomatoes were measured in terms of the L* value and the hue angle (h°), as shown in Table III. Both the h and L* value were significantly ($P<0.05$) influenced by the microclimate, cultivar, storage condition and the storage time. The tomatoes grown in the FPVT had an overall 7.2% higher L* value, representing the four cultivars for the 28 days of storage, compared to those from the NVT. Similarly, the h for the FPVT grown tomatoes was 8% higher than that of the NVT-grown tomatoes. In general, the overall average L* and h, over the 28 day observation period, for cultivar Bona were 13.4-17.5% and 15.9-20.9% lower than those of the other three cultivars (Star 9009, Star 9037 and Zeal), respectively. This result is in agreement with the findings of [9]. There were no significant ($P>0.05$) differences between Star 9037, Star 9009 and Zeal L* and h° values. Tomatoes stored under cold storage had an overall average L* value and an h° that were 6.4% and 8.8% higher, respectively, than those at ambient air storage, for the 28 day observation period. In addition, the h° and L* values decreased progressively over the time of storage and the minimum values were reached on the last day (Day 28) of measurement.

There were also significant ($P<0.01$) effects on the h° and the L* values of the tomatoes, due to the interaction of microclimate × cultivar, microclimate × storage conditions, over the 28 day storage period, cultivar × storage time for both the NVT- and the FPVT-grown tomatoes for the 28 day storage period, as well as storage conditions × storage time for both NVT- and FPVT-grown tomatoes representative of the four cultivars. The L* and h° of Star 9037 were 14.5% and 11.7% higher, respectively, for tomatoes from the FPVT than the ones grown in the NVT. Similarly, Zeal grown under FPVT conditions had L* and h° values that were found to be 14.5% and 12.5% higher, respectively, when compared to those grown in the NVT. Under FPVT microclimate conditions, the L* and h° values of Bona were 21% and 23% lower, respectively, than those of the other three cultivars. On the other hand, under the NVT conditions, the overall mean L* and h° were 12.4-13.2% and 12-14.6% lower, respectively, than those of Star 9037 and Star 9009, for the entire 28 day storage period.

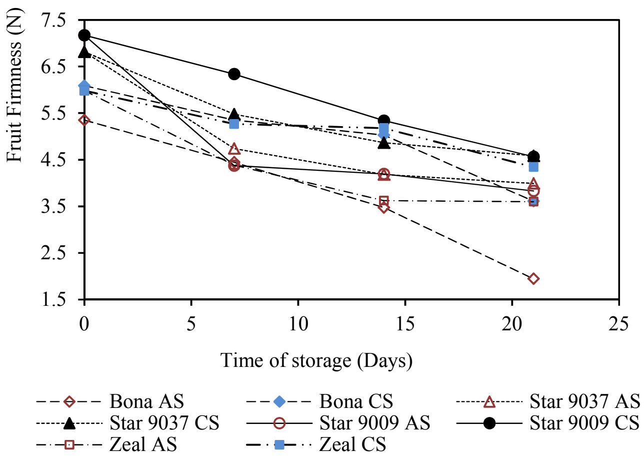

Fig. 4 The interaction effect of cultivar × storage condition × storage time on the firmness of the tomatoes. NV = natural ventilation; FPV = fan-pad evaporative cooling; AS = ambient air storage; CS = cold storage

Tomatoes raised in the FPVT and stored under ambient air conditions, had a 10.4% higher L* and h° that was 12.7% greater than the values obtained for those produced under the NVT microclimate and stored under ambient conditions. Tomatoes grown in the FPVT and stored under refrigerated conditions had L* and h° values that were 13.4% and 16.5% higher than those grown in the NVT and stored under ambient conditions, respectively. The decline of the L* and the h° values was more rapid under ambient than cold storage conditions. Under ambient storage conditions, the L* and h° values decreased by 51.3% and 52.6%, respectively, throughout the storage period, compared to 27.1% and 39.4%, respectively, in cold storage.

Figs. 5 and 6 show that the L* and h° values of cultivar Bona differed significantly (P<0.05) from and decreased more rapidly, when compared to Star 9037, Star 9009 and Zeal. Bona L* and h fell from 65.6 to 24.1 and from 77.8 to 23.4°, respectively, whereas Star 9037 fell from 67.9 to 53.4 and from 80.3 to 56.5°, respectively. During the last seven days of storage, the L* and h° of Zeal fell rapidly from 54.8 to 37.3 and from 63.1 to 37.3°, respectively, compared to those of Star 9009 (from 55.3 to 51.3 and from 63.8 to 53.7°) and Star 9037 (from 55.1 to 53.4 and from 62.6 to 56.5°), respectively. The cultivars Star 9009 and Star 9037 maintained higher L* and h° values throughout the storage period. Tomato colour pigmentation is controlled by many genes [10] and genotypes with high concentrations of the pigment genes have a richer colour than those with less [11], [12]. This could explain the differences in colour among the tomato cultivars used in this study. The results agree with [12]-[14], who reported appreciable colour variations between cultivars.

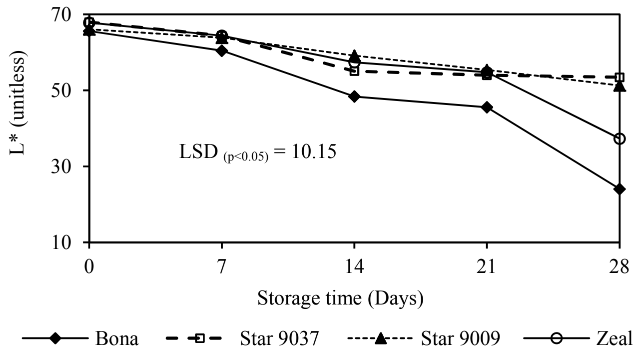

Fig. 5 Interaction effect of cultivar and storage time on L* (a) and h° (b) of tomatoes

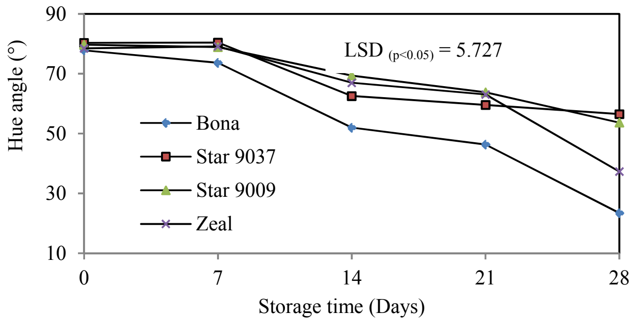

Fig. 6 Interaction effect of cultivar and storage time on h of tomatoes

The interaction between microclimate, cultivar and storage conditions significantly (P<0.001) influenced the L* and the h° values of the tomatoes. Cultivar Bona, grown under FPVT conditions and kept under cold storage conditions had L* and h° values that were 18% and 18.3% higher, respectively, than NVT-grown Bona stored in cold storage. Cultivar Zeal, stored under cold storage, had L* and h° values that were found to be 23.5% and 30.6% higher, respectively, than those stored under ambient conditions. Similarly, Bona tomatoes grown in the FPVT and stored under refrigerated conditions had L* and h° values that were found to be 16.9% and 18.6% higher, respectively, than those stored under ambient conditions.

TABLE II
THE FIRMNESS (N) FOR TOMATOES RAISED UNDER FPVT AND NVT AND STORED UNDER AMBIENT AND COLD CONDITIONS

Ventilation	Cultivar	Ambient storage period (Days)					Cold storage period (Days)				
		0	7	14	21	28	0	7	14	21	28
FPVT	Bona	5.36^{d-j}	4.19^{k-t}	3.56st	3.50st	D	5.36^{d-j}	5.98^{c-g}	4.91^{g-p}	3.50st	D
	Star 9037	7.16^{ab}	4.60^{h-t}	3.97^{n-t}	3.80^{o-t}	D	7.16^{ab}	5.25^{e-l}	4.70^{h-r}	4.58^{h-t}	D
	Star 9009	6.35^{b-e}	4.72^{h-r}	4.30^{j-t}	3.81^{o-t}	D	6.35^{b-e}	5.64^{d-h}	5.14^{f-m}	4.74^{h-r}	D
	Zeal	6.46^{b-d}	4.89^{g-p}	3.72^{q-t}	3. 61^{r-t}	D	6.46^{b-d}	5.35^{d-k}	4.63^{h-s}	3.75^{p-t}	D
NVT	Bona	6.20^{b-f}	4.70^{h-r}	3.89^{n-t}	3.45st	D	6.20^{b-f}	5.35^{d-k}	5.15^{f-m}	3.72^{q-t}	D
	Star 9037	6.47^{b-d}	4.88^{g-q}	4.40^{i-t}	4.18^{k-t}	D	6.47^{b-d}	5.71^{d-h}	5.15^{f-m}	4.47^{i-t}	D
	Star 9009	7.99^{a}	4.10^{l-t}	4.03^{m-t}	3.85^{n-t}	D	7.99^{a}	7.04^{a-c}	5.55^{d-i}	4.39^{i-t}	D
	Zeal	5.51^{d-i}	3.88^{n-t}	3.64^{r-t}	3.48st	D	5.91^{d-g}	5.51^{d-i}	5.01^{g-m}	4.93^{g-o}	D
LSD $_{(p\leq 0.05)}$ = 0.9255; CV = 16.60%											

Mean values in the same column with the same superscript letters indicates no significant differences (P>0.05). The letter D represents "decayed".

TABLE III
THE HUE ANGLE AND L* VALUES FOR FOUR TOMATO CULTIVARS HARVESTED FROM AN FPVT AND A NVT STORED UNDER AMBIENT AND COLD STORAGE

L*

Ventilation	Cultivar	Ambient storage period (Days)					Cold storage period (Day)				
		0	7	14	21	28	0	7	14	21	28
FPVT	Bona	64.21^{a-h}	58.86^{e-l}	46.09^{v-y}	47.74^{t-x}	D	64.21^{a-h}	61.54^{a-k}	48.24^{s-x}	44.51^{w-y}	45.99^{w-y}
	Star9037	67.46^{ab}	66.34^{a-d}	55.52^{j-r}	58.58^{e-l}	58.13^{f-m}	67.21^{ab}	65.74^{a-e}	55.24^{j-r}	62.88^{a-i}	57.09^{h-o}
	Star9009	66.80^{ab}	66.11^{a-d}	61.73^{a-k}	59.24^{d-l}	58.86^{e-l}	66.81^{ab}	63.24^{a-h}	66.95^{ab}	55.59^{j-r}	47.27^{u-x}
	Zeal	67.69^{a}	67.21^{ab}	59.23^{d-l}	53.52^{l-u}	54.79^{k-t}	67.69^{a}	66.46^{a-c}	62.84^{a-i}	56.51^{i-p}	51.53^{m-w}
NVT	Bona	66.99^{ab}	59.63^{c-l}	49.97^{p-w}	49.54^{p-x}	D	66.95^{ab}	61.71^{a-k}	49.24^{q-x}	40.41^{y}	50.21^{o-w}
	Star9037	65.27^{a-f}	64.29^{a-g}	50.31^{o-w}	50.35^{o-w}	53.15^{l-v}	65.27^{a-f}	61.72^{a-k}	57.63^{g-n}	56.25^{i-q}	45.89^{w-y}
	Star9009	68.30^{a}	62.14^{a-j}	54.83^{k-t}	50.36^{o-w}	49.55^{p-x}	68.49^{a}	63.23^{a-h}	50.34^{o-w}	48.39^{s-x}	48.99^{r-x}
	Zeal	67.94^{a}	59.44^{c-l}	47.25^{u-x}	50.71^{n-w}	D	67.94^{a}	64.48^{a-g}	60.24^{b-l}	58.29^{f-m}	42.92^{xy}
LSD $_{(p\leq 0.05)}$ = 5.727; CV = 7.36%											

Hue Angle(°)

Ventilation	Cultivar	Ambient storage period (Days)					Cold storage period (Days)				
		0	7	14	21	28	0	7	14	21	28
FPVT	Bona	77.6^{a-g}	64.7^{h-r}	48.5^{w-z}	48.7^{w-z}	D	77.6^{a-g}	78.0^{a-g}	50.1^{u-z}	44.3^{z}	43.0^{z}
	Star9037	79.2^{a-f}	82.5^{a-c}	61.4^{k-v}	66.7^{f-p}	63.9^{i-s}	79.2^{a-f}	81.9^{a-c}	64.0^{i-s}	81.1^{a-d}	61.0^{k-w}
	Star9009	78.9^{a-f}	83.8^{ab}	70.5^{c-l}	68.3^{e-n}	65.6^{g-q}	78.9^{a-f}	82.2^{a-c}	82.0^{a-c}	68.5^{d-m}	47.7^{yz}
	Zeal	77.9^{a-g}	85.3^{a}	63.1^{i-u}	60.4^{k-x}	60.3^{k-x}	77.9^{a-g}	81.0^{a-e}	77.0^{a-h}	62.0^{j-v}	48.6^{w-z}
NVT	Bona	78.1^{a-g}	70.2^{c-l}	51.2^{t-z}	52.0^{s-z}	D	78.1^{a-g}	81.7^{a-c}	58.1^{l-z}	40.4^{z}	50.7^{u-z}
	Star9037	81.4^{a-c}	74.6^{a-i}	58.7^{l-z}	52.7^{r-z}	53.2^{q-z}	81.4^{a-c}	82.8^{a-c}	54.3^{p-z}	49.6^{v-z}	47.9^{x-z}
	Star9009	80.5^{a-e}	74.8^{a-i}	53.7^{q-z}	54.8^{o-z}	57.1^{m-z}	80.5^{a-e}	74.9^{a-i}	71.5^{b-k}	63.7^{i-t}	44.2^{z}
	Zeal	79.1^{a-g}	66.9^{f-o}	46.6^{z}	55.9^{n-z}	D	79.1^{a-f}	83.4^{ab}	81.3^{a-d}	73.9^{a-j}	40.4^{z}
(LSD $_{(p\leq 0.05)}$ = 10.15; CV = 11.35%											

TABLE IV
THE TOTAL SOLUBLE SOLIDS (°BRIX) OF THE TOMATOES GROWN IN THE FPVT AND THE NVT AND STORED UNDER AMBIENT AND COLD STORAGE CONDITIONS

Ventilation	Cultivar	Ambient storage period (Days)					Cold storage period (Days)				
		0	7	14	21	28	0	7	14	21	28
FPVT	Bona	5.2^{i-p}	7.3^{a}	5.8^{c-m}	6.7^{a-e}	D	5.2^{i-p}	6.4^{a-i}	7.0^{a-c}	5.2^{h-p}	D
	Star9037	4.5^{n-p}	4.4^{o-p}	4.9^{j-p}	4.8^{l-p}	D	4.5^{n-p}	5.0^{j-p}	5.2^{i-p}	4.9^{k-p}	5.2^{h-p}
	Star9009	5.0^{j-p}	4.9^{j-p}	6.2^{a-j}	5.5^{d-p}	D	5.0^{j-p}	5.0^{j-p}	5.1^{i-p}	4.9^{j-p}	5.0^{j-p}
	Zeal	4.3^{p}	5.2^{i-p}	4.8^{l-p}	6.4^{a-i}	D	4.3^{p}	4.9^{j-p}	5.1^{i-p}	4.8^{l-p}	5.2^{h-p}
NVT	Bona	4.6^{m-p}	6.6^{a-f}	5.1^{i-p}	6.1^{b-l}	D	4.6^{m-p}	6.5^{a-g}	6.8^{a-d}	7.3^{a}	5.2^{i-p}
	Star9037	5.2^{i-p}	5.7^{c-n}	5.6^{d-o}	5.2^{i-p}	D	5.2^{h-p}	5.5^{d-p}	5.3^{g-p}	5.8^{c-n}	6.1^{a-k}
	Star9009	5.0^{j-p}	5.6^{d-o}	5.4^{f-p}	5.8^{c-m}	D	5.0^{j-p}	5.7^{c-n}	5.9^{c-l}	5.8^{c-n}	5.1^{i-p}
	Zeal	5.0^{j-p}	6.7^{a-e}	5.8^{c-n}	6.1^{a-k}	D	5.0^{j-p}	5.9^{c-l}	6.5^{a-g}	6.5^{a-g}	5.5^{e-p}
LSD $_{(p\leq 0.05)}$ = 1.006; CV = 14.91%											

Mean values in the same column with the same superscript letters indicates no significant differences (P>0.05). The letter D represents "decayed".

As shown by Figs. 7 and 8, the overall average L * and h° values of tomatoes grown in the NVT and stored under ambient air conditions, decreased significantly (P<0.001) faster than those grown in the NVT and stored under cold conditions, starting from Day 7 of storage. The L* and h° of tomatoes grown in the NVT and stored under cold conditions, decreased at the same rate as those from the FPVT and stored under ambient air and cold storage conditions.

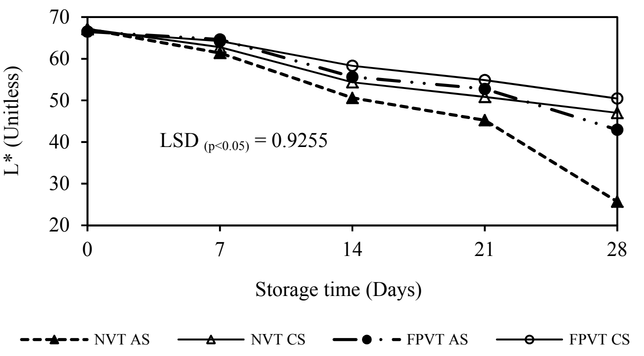

Fig. 7 Interaction of microclimate, storage condition and time of storage on the L*value of the tomatoes

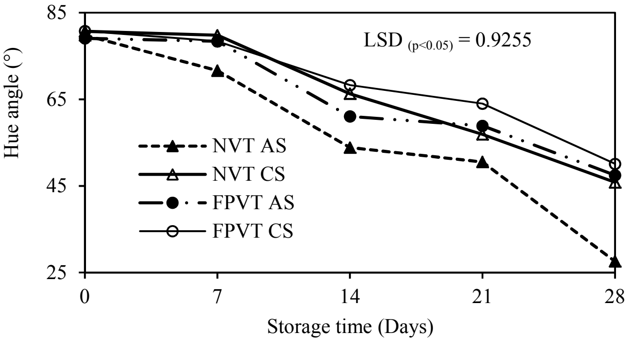

Fig. 8 Interaction of microclimate, storage condition and storage period on the h° of the tomatoes

C. Total Soluble Solids

Table IV shows the effects of microclimate conditions, cultivar differences and storage conditions on the total soluble solids (TSS) of the tomatoes, stored over a 28 day period. Significant (P<0.05) differences resulting from the effect of microclimate, cultivar, storage condition and storage time were observed on the TSS content of tomatoes (Fig. 9). In general, the NVT-grown tomatoes had an overall TSS content that was 10.3% higher than that of the FPVT-grown tomatoes. Cultivar Bona tomatoes had a significantly (P<0.05) higher TSS content than Star 9037 tomatoes, but not significantly (P>0.05) different to those of Zeal and Star 9009. The overall average TSS content of Bona tomatoes was 8.3% higher, when compared to that of the cultivar Star 9037.

Generally, tomatoes stored under ambient air conditions had an overall average TSS content that was 17.7% higher than that of the tomatoes in cold storage. With regards to the effect of the storage period, the overall average TSS content of the tomatoes increased by 15.2% between Days 0 and 7, but did not differ significantly between Days 7 and 21. During the last seven days of storage, the TSS content of the tomatoes fell by 59% which is in agreement with [7].

Significant (P<0.001) differences arising from the interaction of microclimate with storage conditions were observed on the TSS content of tomatoes grown in the NVT. In general, the tomatoes stored under refrigerated conditions had an overall 22.3% lower TSS content than those under ambient air storage. Similarly, the interaction between cultivar and storage time significantly (P<0.001) influenced the TSS content of cultivars Bona and Zeal for both NVT- and FPVT-grown tomatoes stored under both cold and ambient storage condition. The TSS content of Bona and Zeal increased by 27.2% and 18.3% over the first seven days of storage, respectively, but the changes that occurred between Days 7 and 21 were not significant at P=0.05. The TSS content of cultivars Star 9037 and Star 9009 were not significantly influenced by storage time during the first 21 days of storage. During the last seven days of storage, the TSS content of all the tomatoes fell by >50%. In the same manner, the interaction between storage condition and storage time had a significant (P<0.001) influence on the TSS content of all the tomatoes, particularly during the last seven days of storage. During the first 21 days of storage, the TSS content of the tomatoes kept under cold storage conditions and those under ambient air storage did not differ significantly. Significant differences were observed between Days 21 and 28, where the tomatoes under ambient air conditions had rotted and TSS could not be determined. Tomatoes in cold storage had a TSS content of 4.7°Brix on Day 28 of storage.

The three-way interaction of microclimate × cultivar × storage conditions had a significant (P<001) effect on the TSS content of the tomatoes, as well as microclimate × cultivar × storage condition (P<0.001). As shown in Fig. 4, all tomatoes from the NVT, for all the cultivars, had TSS contents that were 20.0-26.2% higher under ambient conditions, compared to cold storage conditions. From the FPVT, only cultivar Star 9037 tomatoes had a TSS content that was 25.2% higher under ambient conditions, compared to cold storage conditions.

Fig. 10 shows that the interaction effects of microclimate with cultivar and storage time significantly (P<0.001) influenced the TSS content of the tomatoes. The TSS contents of Bona tomatoes grown under the FPVT and NVT microclimates were observed to increase the most over the storage period, particularly during the first seven days, when compared to the other cultivars. Between Days 21 and 28, the TSS of cultivar Bona could not be measured due to extreme decay. For cultivars Star 9037, Star 9009 and Zeal grown in the FPVT, the TSS content increased the least over the first 21 days of storage. Between Days 21 and 28, the TSS content of all cultivars, except Bona grown in the FPVT, decreased substantially by 44.2 to 60.3%. Under cold storage conditions, Star 9037 tomatoes grown in the FPVT had a TSS content that was 25.2% higher than those under ambient air storage conditions.

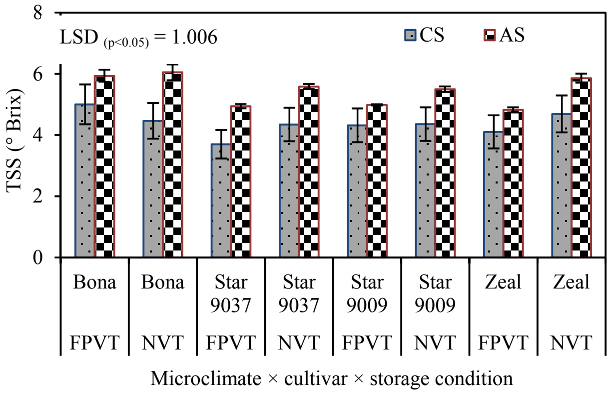

Fig. 9 The interaction effect of microclimate, cultivar and storage condition interaction on the TSS content of the tomatoes. FPVT = fan-pad evaporatively cooled tunnel microclimate, NVT= naturally-ventilated tunnel microclimate; AS= ambient storage conditions; CS = cold storage conditions

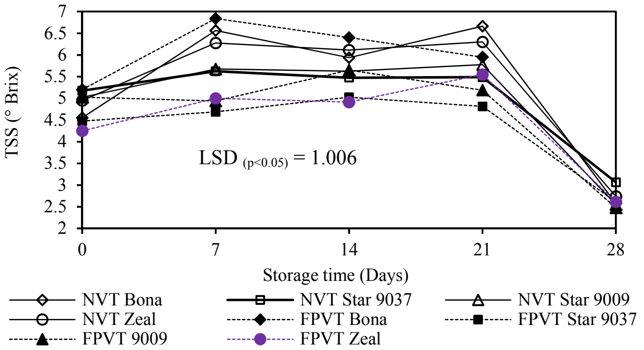

Fig. 10 The interaction effects of microclimate with cultivar over the 28-day storage period

The interaction between microclimate, storage condition and storage period had a significant (P<0.001) effect on the TSS content of the tomatoes (Fig. 11). During the first seven days of storage, the TSS content of tomatoes grown in the NVT increased by 19.9% under ambient air storage conditions and by 16.8% in cold storage. Significant differences (P<0.05) also occurred in all tomatoes, except those harvested from the NVT and stored in cold storage, during the last seven days. This was because all the tomatoes, with the exception mentioned above, had decayed by Day 28. There were variations in the TSS content of the tomatoes from both the NVT and the FPVT during the storage time, but these were not significant at P= 0.05.

Significant differences were also observed in the TSS content with respect to the interaction effects of cultivar with storage condition and storage period. Cultivars Bona and Zeal tomatoes, stored under ambient conditions, had a 30% and 22% increase in the TSS content during the first seven days of storage, respectively. Significant differences (P<0.05) were also observed on all tomatoes from the four cultivars, during the last seven days in storage, primarily because the tomatoes had decayed and testing could not be performed. Similarly, under cold storage conditions, the TSS content of Bona tomatoes increased by 24.2% between Days 0 and 7. Conversely, under cold storage conditions, cultivars Star 9037, Star 9009 and Zeal tomatoes were not influenced by the interaction throughout the 28 days of storage.

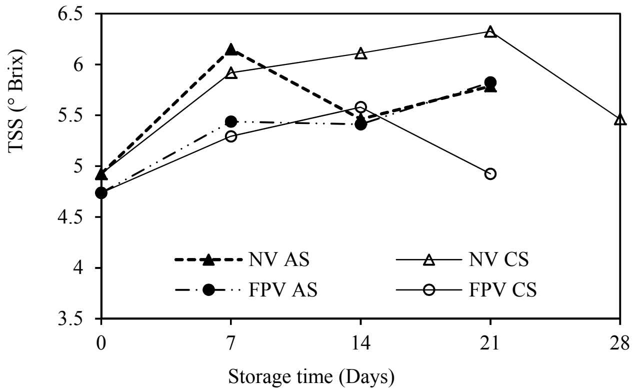

Fig. 11 The interaction effects of microclimate with storage condition over the 28-day storage period

D.pH Value

Significant (P<0.001) cultivar effects were observed on the pH of the tomatoes (Table V). In general, cultivar Zeal had the highest overall pH value of 3.84, followed by Star 9037 with 3.82, then Star 9009 with 3.74, and lastly, Bona with 3.64 for the entire storage period. The pH of cultivar Bona was significantly lower than that of Star 9037 (by 4.6%) and Zeal (by 5.0%), but not significantly different to that of Star 9009. The storage conditions significantly (P<0.001) influenced the pH value of the tomatoes. According to [15], the effect of environmental conditions on the acidity of tomato fruits is intricate. Refernece [16] suggested that organic acids responsible for the acidity of tomatoes are synthesized from stored carbohydrates in the fruits, whereas [17] suggested that some of the organic acids are translocated from the roots and plant leaves. Under refrigerated storage conditions, the pH level was 18.8% higher than that of the tomatoes stored under ambient air conditions. This could be due to the consumption of the organic acids under higher respiration rates associated with storage at higher temperatures [18]. Similarly, the storage period had a significant (P<0.001) influence on the pH value of the tomatoes. The pH values of the tomatoes decrease significantly by 6.4%, during the first seven days of storage, and by a further 56.5% between Days 21 and 28. Between Days 7 and 21, there were no significant differences in the pH values. The microclimate conditions were found to have a non-significant (P>0.05) effect on the pH values of the tomatoes.

As shown in Table V, there were significant (P < 0.01) interaction effects from: (a) microclimate × cultivar; (b) microclimate × storage condition; (c) microclimate × storage time; (d) cultivar × storage condition; (e) cultivar × storage time; and (f) storage condition × storage time. Under the NVT microclimate, the pH of cultivar Bona tomatoes was 10.3% higher than that of Bona tomatoes from the FPVT. The effect of microclimate on the organic acids of tomato fruit is complex. References [15] and [16] suggested that organic acids are synthesized in the fruit, while [17] suggested that some may be translocated from the leaves and roots. There were no significant differences in the pH value of the other cultivars grown in the NVT and tomatoes of the same cultivar in the FPVT.

With regards to the interaction of microclimate with storage condition, the pH of tomatoes grown under NVT conditions and stored under cold conditions was 19.8% higher than that of the tomatoes from the NVT, but stored under ambient air conditions. Similarly, the pH of tomatoes from the FPVT and stored in cold storage, was 17.8% higher than those from the FPVT and stored under ambient air conditions. With regards to the effect of the microclimate × storage time, the pH value of tomatoes grown in the NVT decreased significantly by 6.9% during the first seven days. During the last seven days of storage, the pH content of the tomatoes decreased by 50.1%. Similarly, the pH of tomatoes from the FPVT decreased significantly by 6.0% during the first seven days and also significantly by 8.7% during the last seven days. Between Days 7 and 21, the pH level of the tomatoes from the NVT and the FPVT did not vary significantly, but increased slightly.

Under cold storage conditions, the pH values of tomatoes from all the cultivars were found to be significantly higher than under ambient air storage. The pH value of cultivar Bona tomatoes was found to be 10.6% higher under cold storage conditions, with a pH of 3.85, than those under ambient air storage, which had a pH value of 3.49. Similarly, Star 9037 tomatoes in cold storage had a pH of 4.28, which was 21.3% higher, when compared to that of tomatoes of the same cultivar, but under ambient storage. The pH value of Star 9009 tomatoes was 19.8% higher when stored in refrigerated conditions, compared to a pH value of 3.33 without refrigeration. For cultivar Zeal, the pH value of the tomatoes was 4.33 in cold storage, 22.6% higher than those stored under ambient air conditions. With regards to the effect of the interaction of cultivar with storage time, the pH values decreased significantly by 6.5 to 9.0% for all cultivars, except Star 9009 between Days 0 and 7. The pH values of all the cultivars also decreased substantially by 49 to 74% during the last seven days of storage (Fig. 12). The effect of the interaction of storage condition with storage period was found to decrease the pH of the tomatoes stored under ambient air conditions by 7.6% over the first seven days of storage. The pH values of the tomatoes increased significantly by 5.5% between Days 14 and 21, under conditions of ambient air storage, but the tomatoes had decayed by Day 28. Conversely, under cold storage conditions, the pH value of the tomatoes fell significantly by 5.3% over the first seven days and by a further 11.7% between Days 21 and 28.

The three-way interaction effects of the treatments on the pH of the tomatoes were also observed. The microclimate × cultivar × storage condition interaction significantly (P<0.001) influenced the pH of the tomatoes, as did microclimate × cultivar × storage time (P<0.001). Among the tomatoes grown in the NVT, the pH values of the tomatoes for all the cultivars were higher (18.9 to 20.5%) under cold storage conditions, when compared to those under ambient air storage. Similarly, for FPVT-grown tomatoes, the pH values of cultivars Star 9037, Star 9009 and Zeal were 20.8 to 24.5% higher under cold storage than ambient air storage conditions. With regards to the interaction of microclimate × cultivar × storage time, the pH values for cultivars Bona, Star 9009 and Zeal raised under the NVT microclimate, decreased by 7.1-10.6% during the first seven days of storage. During the last seven days of storage, the pH decreased substantially by 48.5 to 52.3% for all the cultivars grown in the NVT. Similarly, for the tomatoes grown in the FPVT, the pH values of the cultivars Bona, Star 9037 and Star 9009 tomatoes in cold storage, fell by 10.8%, 4.3% and 5.6%, respectively, during the first seven days of storage. The acidity determines the taste and flavour of tomatoes [19], [20]. According to [21], the best tomato flavour is achieved by an interaction of high sugar content and relatively high acidity level.

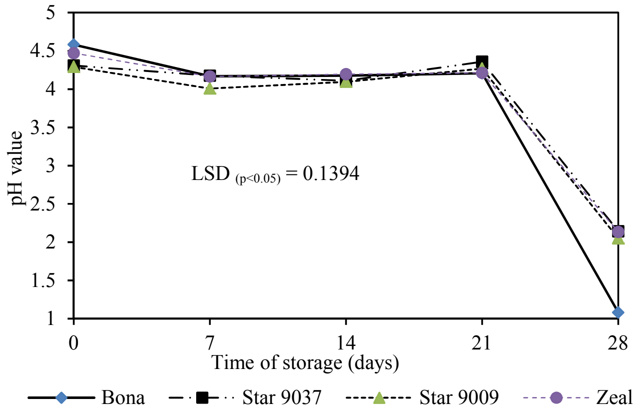

Fig. 12 The change in pH of tomatoes during 28 days of storage

The pH values of the tomatoes were further influenced by the three-way interactions of: (a) microclimate × storage condition × storage time (P<0.001), and (b) cultivar × storage condition × storage time (P<0.001). The pH values of sample tomatoes grown in the NVT decreased significantly by 4.1%, when stored in the climate chamber, as opposed to an 8.9% decrease under ambient air storage. The pH values of the tomatoes then increased by 4.1% under ambient storage, between Days 14 and 21. Conversely, the pH values of the tomatoes grown in the FPVT and stored under ambient air conditions, decreased significantly by 6.9% between Days 14 and 21. By Day 28, the tomatoes stored under ambient air conditions had decayed to such an extent that the pH could not be determined. Under cold storage, the pH values of the tomatoes from the FPVT decreased significantly by 25.1% between Days 21 and 28. In addition, the change in the pH over the storage period did not vary significantly for tomatoes of the same cultivar grown in the FPVT and the NVT. For example, Bona tomatoes from the NVT were not significantly different to those grown in the NVT with regards to their pH values.

TABLE V
THE pH VALUES OF TOMATOES GROWN IN FPVT AND NVT AND STORED UNDER AMBIENT AND COLD STORAGE CONDITIONS

Ventilation	Cultivar	0	7	14	21	28
Ambient storage period (Days)						
FPVT	Bona	4.67^{a}	4.06^{p-u}	4.07^{o-u}	4.29^{e-m}	D
	Star 9037	4.42^{c-e}	4.18^{i-s}	4.20^{h-r}	4.39^{c-g}	D
	Star 9009	4.32^{d-l}	4.16^{k-t}	3.89^{v}	4.37^{c-h}	D
	Zeal	4.60^{ab}	3.97^{u-v}	4.01^{s-v}	4.24^{f-p}	D
NVT	Bona	4.50^{bc}	4.03^{r-v}	4.24^{f-o}	4.29^{e-m}	D
	Star 9037	4.20^{c-e}	4.06^{p-u}	4.13^{m-u}	4.40^{c-f}	D
	Star 9009	4.26^{e-n}	3.89^{v}	4.13^{m-u}	4.37^{c-h}	D
	Zeal	4.61^{ab}	3.98^{u-v}	4.15^{l-t}	4.39^{c-g}	D
Cold storage period (Days)						
FPVT	Bona	0	7	14	21	28
	Star 9037	4.67^{a}	4.14^{m-u}	4.18^{i-s}	4.14^{m-u}	D
	Star 9009	4.42^{c-e}	4.29^{e-m}	4.34^{c-j}	4.47^{b-d}	4.35^{c-i}
	Zeal	$4.32d^{d-l}$	4.14^{m-u}	4.16^{k-t}	4.23^{f-p}	4.16^{k-t}
NVT	Bona	4.60^{ab}	4.21^{h-q}	4.34^{c-i}	4.16^{k-t}	4.21^{h-q}
	Star 9037	4.50^{bc}	4.33^{c-k}	4.11^{n-u}	4.11^{n-u}	4.32^{d-l}
	Star 9009	4.20^{c-e}	4.19^{i-r}	4.09^{n-u}	4.18^{i-s}	4.22^{g-p}
	Zeal	4.26^{e-n}	3.99^{t-v}	4.11^{n-u}	4.11^{n-u}	4.04^{q-v}
	Bona	4.61^{ab}	4.22^{g-q}	4.16^{k-t}	4.16^{k-t}	4.10^{n-u}
LSD $_{(p \leq 0.05)}$ = 0.1394; CV = 2.60%						

Mean values in the same column with the same superscript letters indicates no significant differences (P>0.05). The letter D represents "decayed".

IV. CONCLUSION

This study was undertaken to determine the combined effects of greenhouse microclimate, postharvest storage environment, as well as cultivar and storage period on the postharvest quality of four fresh market tomatoes. The tomatoes grown under the better conditions in the more costly FPVT were less firm and lost firmness more rapidly than those raised in the NVT. However, the colour change was more rapid for tomatoes grown in the NVT. In addition, cultivar Bona had the lowest firmness and lost firmness more rapidly under both NVT and FPVT microclimates. Cold storage conditions at 13°C and 85% RH helped FPVT-grown tomatoes, as well as cultivars Bona and Zeal tomatoes, to maintain a firmer texture for an extended period than when the tomatoes were stored under ambient conditions. The cultivars Star 9009 and Star 9037 had the firmest texture, especially when grown under the NVT microclimate. This research has shown that naturally-ventilated and fan-pad evaporatively-cooled greenhouse microclimates have a significant effect on the postharvest quality and storability of tomatoes. The study has also provided an understanding of how integrated agro-technologies affect postharvest quality of fresh produce. The less costly, naturally-ventilated greenhouse produced tomatoes that were firmer, with a higher TSS content than the more expensive fan-pad evaporatively cooled tunnel. Under the FPVT microclimate, ripening (in terms of colour change) was slower. Cold storage helped the FPVT-grown tomatoes to maintain a firmer texture and the NVT-grown tomatoes to ripen relatively slower than under ambient conditions. The study has also shown that there is a need for further research on integrated agro-technologies to address the information gap of the multi-factorial interactions of greenhouse microclimate, cultivar and storage conditions, to provide the scientific background on the exact nature of the influence.

REFERENCES

[1] DAFF, Production guidelines for tomato. Directorate on Agricultural Information Services, Pretoria, South Africa. Available from: www.daff.gov.za/publications. (Accessed 25 March 2013).

[2] H. Hanna, Influence of cultivar, growing media, and cluster pruning on greenhouse tomato yield and fruit quality. HortTechnology, 2009, vol. 19, no. 2, pp. 395-399.

[3] M.M. Maboko, C.P. du Plooy, and I. Bertling, Performance of tomato cultivars in temperature and non-temperature controlled plastic tunnels. In: eds. Castilla, N, van Kooten, O, Sase, S, Meneses, JF, Schnitzler, WH and van Os, E, Proceedings of the XXVIII[th] International Symposium on Greenhouse and Soilless Cultivation. ActaHort 927, Lisbon, Portugal, 2010, pp. 405-411.

[4] R.G.Snyder, Greenhouse Tomato Handbook. (Internet). Publication 1828, Mississippi State University Extension Service, Starkville, USA. Available from: http://www.msucares.com/pubs/publications/pub1828.htm. (Accessed 15 August 2003).

[5] C.E. Sams, Pre-harvest factors affecting postharvest texture. Postharvest Biology and Technology, 1999, vol. 15, no. 3, pp. 249-254.

[6] P. Sirisomboon, M. Tanaka and T. Kojima, Evaluation of tomato textural mechanical properties. Journal of Food Engineering, 2012, vol. 111, no. 4, pp. 618-624.

[7] Gorini, FL and Testoni, A. 1990. The relation between colour and quality of vegetables. In: eds. Jordan, JL, Workshop on Measuring Consumer Perception of Internal Product Quality, 31-60. Acta Hort 259, Wageningen, the Netherlands.

[8] Genanew, T. 2013. Effect of post-harvest treatments on storage behaviour and quality of tomato fruits. World Journal of Agricultural Sciences vol. 9, no. 1, pp. 29-37.

[9] L.A.F. Camelo, and P.A. Gómez, Comparison of colour indexes for tomato ripening. Horticultura Brasileira 2004, vol. 22, no. 3, pp. 534-553.

[10] J.R. Stommel, and K.G. Haynes, Inheritance of beta carotene content in the wild tomato species Lycopersicon cheesmanii. Journal of Heredity 1994, vol. 85, no. 5, 401-404.

[11] R.L. Jarret, H. Sayama, and E.C. Tigchelaar, Pleiotropic effects associated with the chlorophyll intensifier mutations high pigment and dark green in tomato. Journal of the American Society for Horticultural Science 1984, vol. 109, no. 6, pp. 873-878.

[12] E.J. Sacks and D.M. Francis, Genetic and environmental variation for tomato flesh colour in a population of modern breeding lines. Journal of the American Society for Horticultural Science, 20011, vol. 26, no. 2, 221-226

[13] S. Brandt, Z. Pék, and E. Barna, Lycopene content and colour of ripening tomatoes as affected by environmental conditions. Journal of the Science of Food and Agriculture, 2006, vol. 86, no. 4, 568-572.

[14] A. Radzeviius, R. Karklelien, P. Viškelis, R. Bobinait and S. Sakalauskien, Tomato (Lycopersicon esculentum Mill.) fruit quality and physiological parameters at different ripening stages of Lithuanian cultivars. Agronomy Res., 2009, vol. 7, no. 2, pp. 712-718.

[15] F.R.B. Caliman, F.J.H. Da Silva, , P.C. Stringheat, P.C.R. Fontes, G.R. Moreira and E.C. Mantovani, Quality of tomatoes grown under a protected environment and field conditions. IDESIA (Chile), 2010, vol. 28, no. 2, pp. 75-82.

[16] R. Sakiyama and M.A. Stevens, Organic acid accumulation in attached and detached tomato fruits. Journal of the American Society for Horticultural Science, 1976, vol. 101, no. 2, pp. 394-396.

[17] Bertin, N, Ghichard, N, Leonardi, C, Longuenesse, JJ, Langlois, D and Naves, B. 2000. Seasonal evolution of the quality of fresh glasshouse tomato under Mediterranean conditions, as affected by vapour pressure deficit and plant fruit load. Annals of Botany vol. 85, no. 6,741-750.

[18] ME Saltveit, 2003. Respiratory metabolism. In: eds. Gross, KC, Wang, CY and Saltveit, ME, the Commercial Storage of Fruits, Vegetables and Florist and Nursery Stocks. Agriculture Handbook 66. USDA, Beltsville, USA.

[19] J.W. De Bruyn, F. Garretsen, and E. Kooistra, Variation in taste and chemical composition of the tomato (Lycopersicon esculentum Mill.). Euphytica, 1971, vol. 20, no 2, pp. 214-227.

[20] A.A. Kader, Perspective, Flavour quality of fruits and vegetables. Journal of the Science of Food and Agriculture, 2008, vol. 88, no. 11,1863-1868.
[21] A.A. Kader, Effects of post-harvest handling procedures on tomato quality. In: eds. El-Beltagy, AS and Persson, AR, Symposium on Tomato Production on Arid Land. Acta Hort, 1984, vol. 190, pp. 209-221.