African Journal of Biotechnology Vol. 10(56), pp. 12662-12670, 3 October, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB10.1661
ISSN 1684–5315

Full Length Research Paper

Yield and storability of green fruits from hot pepper cultivars (*Capsicum* spp.)

Awole, S., Woldetsadik, K. and Workneh, T. S.*

School of Bioresources Engineering and Environmental Hydrology, Faculty of Engineering, University of Kwa-Zulu Natal, Private Bag X0l, Pietermaritzburg, Scottsville 3209, South Africa.

Accepted 1 April, 2011

Five hot pepper (*Capsicum* spp.) cultivars were grown using randomized complete block design (RCBD) with three replications. Green peppers were stored under two storage conditions (ambient and evaporative cooling) with three replications. The plant growth characters yield and yield related traits were assessed. Melka Zala, PBC 600 and Mareko Fana had taller plants and had more number of branches. Melka Zala and Melka Dima were observed to be late and early maturing cultivar, respectively. The highest numbers of total marketable fruits were recorded in PBC 600, while the lowest numbers were recorded in Melka Eshet and Melka Zala. The highest mean pod weight and fresh pod yield were recorded in Melka Dima, while the lowest was recorded in PBC 600. Cultivars and storage conditions had significant ($P \leq 0.05$) effect on the shelf life of the peppers. Storage at ambient conditions resulted in high weight loss. The lowest moisture content was recorded in PBC 600. The evaporative cooler reduced weight loss and maintained higher marketability. The lowest weight loss was found in Mareko Fana stored in the evaporative cooler. On day 16, all pepper fruits stored at ambient conditions were unmarketable, while those stored in the evaporative cooler were kept up to 28 days.

Key words: Pepper, yield, cultivar, evaporative cooling, weight loss, moisture content, marketability.

INTRODUCTION

Pepper (*Capsicum* spp.) is grown in many countries of the world and its production for culinary and vegetable uses has been increased from time to time. In Ethiopia today, it is extensively produced and used. It is actually considered as a national spice. Even though no documented information is available, it was introduced to Ethiopia probably by the Portuguese in the 17 century. As a food, pepper has low energy value (25 kcal/100 g), but it is an excellent source of vitamins A (530 IU/100 g) and C (128 mg/100 g) and a good source of vitamin B_2 (0.05 mg/100 g), potassium (195 mg/100 g), phosphorus (22 mg/100 g) and calcium (6 mg/100 g) (Bosland, 1996).

The high nutritive and culinary value of pepper gives them a high demand in the market year round. *Capsicum* spp. is used fresh or dried, whole or ground into powder and alone or in combination with other flavoring agents.

The climatic and soil conditions of Ethiopia allow cultivation of a wide range of fruit and vegetable crops. The country has a vast potential for production of fresh fruit and vegetable varieties for domestic and export markets, primarily for the densely populated urban areas such as Addis Ababa and also, for the neighboring foreign markets such as Djibouti, Somalia and the Middle East (Lemma et al., 1994). However, growing and marketing of fresh produce in Ethiopia is complicated by high postharvest losses which are estimated to reach as high as 25 to 35% of the produced volume for vegetables (Agonafir, 1991). This huge loss is mainly attributed to poor storage facilities, poor means of transportation and handling (Kebede, 1991). Total postharvest losses for hot pepper is estimated to be about 28.6 and 38.7% during the dry and wet seasons, respectively. Bruising is considered to be the major cause of wastage, followed by physiological and pathological damages in the field as well as faulty packing house and storage management

*Corresponding author. E-mail: Seyoum@ukzn.co.za. Tel: +27(0)33-2606140. Fax: +27(0)33-2605818.

Abbreviations: RH, Relative humidity; **PWL,** Physiological weight loss.

(Mohammed et al., 1992). In Ethiopia, there is lack of proper means of postharvest handling of fruits and vegetables and generally, very little emphasis is given to postharvest handling of perishable produce (Tadesse, 1991). Availability of appropriate low cost storage facilities can encourage farmers to increase fruit and vegetable production, since it enables them to withhold the produce without quality deterioration for days or weeks until they could obtain a reasonable sale for their produce. Fresh produce needs low temperature and high relative humidity (RH) during storage and transportation. Therefore, reducing the temperature and increasing the RH are primary means of maintaining product quality during storage and transportation. Reduced temperature decreases physiological, biochemical and microbiological activities, which are the causes of deterioration of quality attributes such as flavour, texture, colour and nutritive value (Thompson et al., 1998).

Amjad et al. (2010) reported result on effect of packaging material and different storage regimes on shelf life and biochemical composition of green hot pepper fruits. Temperature of the surrounding air and produce can be reduced by forced air cooling, hydro cooling, vacuum cooling, ice cooling and adiabatic cooling (Thompson et al., 1998). However, most of these cooling methods are unaffordable by the small-scale peasant farmers, retailers and wholesalers in Ethiopia, as they require high initial cost and power sources. In spite of that, it is essential to control storage temperature and RH during storage, as they are the main causes of fruits and vegetables deterioration during ripening and storage. Low temperature and high RH can be achieved using evaporative cooling (Workneh and Woldetsadik, 2001), which is a very economical and relatively efficient technique to store products than other mechanical refrigerators (Chakraverty et al., 2003). In Ethiopia, research on vegetables in general and chilli in particular has been aimed primarily at identification of new varieties for high yield and disease resistance as well as cultural practices for increasing yield but no information is available on the postharvest quality and shelf life of green fruits of the released cultivars under different storage conditions. Hot pepper varieties have been developed and released by the Ethiopian agricultural research institute but no information is available on the postharvest quality and shelf life of green fruits of the released varieties under different storage conditions. Therefore, the main objective of this study is to look at the agronomic components, yield and some postharvest quality of green pepper. The specific objectives of this study are to determine the yield and postharvest storage quality of different varieties of hot pepper.

MATERIALS AND METHODS

Site description

The experiment was conducted at Haramaya University Experimental Station, site located at Dire Dawa, during the autumn season of 2007/2008. The area is located in the eastern part of the country lying between 9°27 to 9°49'N latitude and 41°38' to 42°9'E longitude. It is located 520 km east of the capital city, Addis Ababa, along the Ethiopia - Djibouti railway. The altitude of the area is about 1100 m.a.s.l. The mean annual rainfall is 520 mm and means maximum and minimum temperatures range from 28 to 34.6°C and 14.5 to 21.6°C, respectively. Soil of the site is sandy loam with a pH of 8.4 (Belay, 2002).

Plant materials

Five cultivars of hot pepper (*Capsicum* spp.) namely Mareko Fana, PBC 600, Melka Zala, Melka Dima and Melka Eshet of hot pepper were used for this study. The first two were released in 1976, while the rest were released in 2004 by the Ethiopian institute of agricultural research (Lemma et al., 1994). In Ethiopia, green fresh hot peppers are consumed together with the most important traditional food such as *injera* with stew. Among the other hot pepper cultivars in the country, the mentioned five cultivars are the most preferred ones. Hence, these five cultivars were selected for their yield and their storability under evaporative cooling or ambient environmental conditions.

Treatments and design of field experiment

The field experiment was executed at Dire Dawa of Haramaya University Farm under irrigation using randomized complete block design with three replications. Seeds of the pepper varieties were raised on nursery bed at Haramaya University main campus and transplanted to the field 55 days after emergence at a spacing of 60 cm between rows and 40 cm between plants. The plots comprised ten rows. The spacing between plots in each replication was 1 m, while the spacing between adjacent replications was 2 m. All plots received recommended cultural practices uniformly (Lemma et al., 1994) including the control of insects and diseases.

Sample preparation and storage experiment

For the postharvest quality and shelf life studies, fruits harvesting was carried out at green mature stage when 50.0% of the plants attained fruits with green maturity stage. Fruits with bruises, sign of infection or those different from the group were discarded from the samples. Uniform, unblemished pepper fruits having similar size and color were then selected and hand washed with tap water to remove soil particles and to reduce microbial population on the surface. Then, the fruits were surface dried with soft cloth and subdivided and stored in evaporative cooler and at room temperature in three replications.

Evaporative cooler

A multi-layer, improved version of evaporative cooler developed by the Food Science and Postharvest Technology, Department of Haramaya University, (Getenit et al., 2008) was used as storage environment in this investigation. The inner dimensions of the unit were 2 x 2 x 1.3 m, having a capacity for about 0.5 ton fruits. The frame was constructed from 25 mm × 25 mm × 4 mm angel iron. The side and the top surface of the cooler are covered with sheet metal (1 mm thickness). The cooler consist of three major units including an air conditioning unit, a watering system and storage chamber (Getenit et al., 2008).

Table 1. Mean plant height, branch number and days to flower and maturity, mean fruit number, fruit weight and yield of hot pepper cultivars.

Cultivar treatment	PH (cm)	BN	DF	DM	TFN/P	MFN/P	UMFN/P	MPW (g)	MY (ton/ha)	TFN/P
Melka Dima	53.6[b]	10.3[c]	66.7[e]	125.0[e]	23.9[b]	20.4[b]	3.4[a]	17.0[a]	20.0[a]	23.9[b]
Melka Eshet	42.7[c]	8.9[d]	87.7[b]	147.7[b]	16.2[c]	14.7[c]	1.2[c]	12.4[b]	11.3[b]	16.2[c]
Melka Zala	59.6[a]	14.1[a]	90.0[a]	150.0[a]	16.9[c]	14.8[c]	2.4[b]	11.3[b]	9.4[bc]	16.9[c]
Mareko Fana	58.1[a]	13.3[ab]	82.0[d]	142.3[d]	24.3[ab]	21.6[b]	2.5[b]	7.4[c]	6.0[c]	24.3[ab]
PBC 600	59.2[a]	12.7[b]	85.0[c]	145.0[c]	27.5[a]	25.4[a]	3.8[a]	6.6[c]	4.7[c]	27.5[a]
Significance	***	***	***	***	**	**	***	***	**	**
SE ±	0.9	0.4	0.6	0.5	1.1	1.0	0.1	0.7	14.4	1.1
LSD (0.05)	2.9	1.3	1.8	1.6	3.4	3.1	0.4	2.3	4.7	3.4
CV (%)	2.9	5.6	1.2	0.6	8.3	8.4	11.2	7.3	24.0	8.3

Means within a column followed by the same letter (s) are not significantly different according to least significant difference test (probability P ≤ 0.05), where ** and *** indicate significant difference at P ≤ 0.01 or 0.001, respectively. PH, Plant height (cm); BN, branch number; DF, days to flowering; DM, days to maturity; TFN/P, total fruit number per plant; MFN/P, marketable fruit number per plant; UMFN/p, unmarketable fruit number per plant; MPW, mean pod weight; MY, marketable yield.

Measurements

Agronomic characteristics, yield and yield components

The heights (cm) of 15 randomly taken sample plants were measured from the ground level to the highest point at blooming stage: The number of primary and secondary branches of 15 randomly taken sample plants of at blooming stage was recorded. Days to 50.0% flowering was recorded when approximately 50.0% of the plants in a plot formed some flowers that were in bloom. Days to fruit maturity was recorded when approximately 70% of the plants in a plot had fruits that attained physiological maturity. The total numbers of physiologically mature fruits per plant were counted over the harvest period on 15 randomly selected plant samples per plot. Using 15 sample plants per plot at each harvest, fruits were categorized as marketable and unmarketable. Fruits which were cracked, damaged by insect, diseases, birds and sunburn, etc. were considered as unmarketable, while fruits which were free of damage were considered as marketable. Mean number and weight of marketable and unmarketable fruits were then calculated to record numbers and weight per plot. Mean pod weight was calculated from fruits of successive harvests from 15 random sample plants, that is, total marketable pod weight of sample plants divided by the total number of marketable fruits harvested. Finally, total weight of fruits free from crack, damage by insect and diseases, etc. from the central three rows over the harvest period was recorded to estimate marketable yield per hectare.

Moisture content

This parameter was determined using 10 g sample from each treatment that was cut into pieces, dried in a forced air circulation oven at 70.0°C to a constant weight as described by Antoniali et al. (2007) and results expressed in percentage.

Physiological weight loss

Physiological weight loss (PWL) was determined following the method described by Waskar et al. (1999). Stored fruits from each treatment were weighed at the start of the experiment and at four days interval for four weeks. The differential weight loss was calculated for each interval and converted into percentage by dividing the change with the initial weight recorded on each sampling interval.

Percentage marketable fruits

The marketable quality of the fruits was subjectively assessed according to Mohammed et al. (1999). On each sampling time, marketability of the fruits was judged using a 1 to 9 rating with 1 = unusable, 3 = unsalable (poor), 5 = fair, 7 = good, 9= excellent to evaluate the fruit quality. The size, color, firmness surface defects, sign of mould growth and shrinkage were used, as visual parameters for the rating. Fruits that received a rating of five and above were considered marketable, while those rated less than five were considered unmarketable.

Statistical procedures

The data were subjected to the analysis of variance for randomized complete block design following the procedure by Gomez and Gomez (1988) using the Statistical Analysis System (SAS) 6.12 version software (SAS Institute Inc., Cary, NC). Least significant difference (LSD) test was used to separate the means at 5, 1 and 0.1% probability levels.

RESULTS AND DISCUSSION

Agronomic characteristics

Significant differences (P ≤ 0.05) were observed in plant height and number of branches among the hot pepper varieties studied (Table 1). The plant height ranged from 42.7 cm in Melka Eshet to 59.6 cm in Melka Zala. Melka Zala, PBC 600 and Mareko Fana had the tallest plants with no significant difference among them. Melka Dima had plants with intermediate height (53.6 cm), while the shortest plants were observed in Melka Eshet. This result is in agreement with that of Engles (1984) who reported that, Ethiopian pepper cultivars have plant height ranges between 18.0 and 77.0 cm and also, with the range of 58.0 to 85.0 cm reported by EARO (2005). Ado (1987) and Gomez et al. (1988) also reported plant height in the range of 47 to 69 cm for different varieties of *Capsicum* spp.

The number of branches in Melka Dima and Melka Eshet were significantly (P ≤ 0.05) lower than the other varieties (Table 1). Melka Zala followed by Mareko Fana, but with no significant difference among them, had the highest number of branches per plant. Melka Eshet had the least number of branches. In general, the tallest plants tended to have more number of branches per plant which was partly due to the increased growing points (nodes) in taller varieties.

Significant (P ≤ 0.05) variations were observed among the hot pepper varieties in the number of days plants attain 50% flowering and 70% physiological maturity. Melka Zala required the longest time (90 days) until 50% of the plants to flower and 150 days until they mature. Melka Dima required the shortest time (67 days) to flower and 125 days to mature. The remaining three varieties were also found to be late relatively with a maturity date ranging from 142.0 to 147.7 days, which were significantly (P ≤ 0.05) different among each other. Ado et al. (1987) reported 127 to 140 days for maturity of different *Capsicum* species. Lemma et al. (1994) also indicated a range of 96 to 99 and 100 to 126 days to flowering and maturity, respectively, for different *Capsicum* genotypes including varieties in the present study. In another study, Geleta (1998) reported 74 to 97 days and 114 to 158 days for flowering and maturity, respectively, of 18 *Capsicum* genotypes grown at Melkassa Research Center. The results indicate that, the traits are affected by both genotype and environment.

Yield and yield components

Both total and marketable fruit number per plant showed significant difference (P ≤ 0.05) among the pepper varieties (Table 1). The highest total and marketable fruits per plant were recorded in PBC 600 followed by Mareko Fana and Melka Dima with no significant difference between the later varieties. Melka Eshet and Melka Zala had the lowest fruit number per plant. The fruit number per plant in this study is in accordance with previous reports by Ado et al. (1987) who observed fruits number per plant ranging from 8 to 70 in 16 *Capsicum* accessions. It is clear that, environmental and genetic factors regulate the number of fruits. Bakker and Uffellen (1988) indicated that the total number of fruits per plant depends on the mean daily temperature. They reported that, as the mean daily temperature increase the number of fruits per plant also increased. Erickson and Markhart (1997) noted that, temperature is the primarily factor in the decrease of fruit production as reduced fruit set was due to flower abortion and not due to decreased flower initiation or plant growth. Cocharn (1964) showed that, the poor fruit set at high temperature to be due to excessive transpiration by the plant which could partly be the cause for the differences observed in this study.

In the present study, unmarketable fruit number per plant were observed to be relatively low, ranging from 7.7% in PBC 600 to 14.4% in Melka Dima (Table 1). Most of the unmarketable fruits were small sized and deformed. Godfrey and Yosef (1992) reported that, from 15.0 to 44.0% fruits of pepper can be unmarketable. However, in the present study percentage of unmarketable fruit was found to be lower.

Mean pod weight of the varieties ranged from 6.6 in PBC to 17.0 g in Melka Dima and was found to be significantly (P ≤ 0.05) different among varieties (Table 1). Ado et al. (1987) reported mean pod weight of 16 pepper varieties to be in the range of 3.3 to 28.6 g, which is in agreement with the present finding. The highest pod weight was recorded in Melka Dima, followed by Melka Eshet and Melka Zala. Mareko Fana and PBC 600, which had the highest number of fruit per plant, recorded the least mean fruit weight (56.0 and 61.0% less than Melka Dima, respectively). In general, as the number of fruits per plant increases, the size of individual fruits tends to be smaller. This could be due to competition among fruits for carbohydrate or due to genetic factors. Restricting fruit set allows the plant to develop and retain large sized fruits (Rylski and Spigelman, 1986). However, Melka Dima was found to have the heaviest fruits though the number of fruits per plant was also relatively high which show better adaptability of the cultivar to the climate of the study area.

There was significant (P ≤ 0.05) difference in the marketable yield of fresh pepper fruits among the varieties which were harvested four times over two months period (Table 1). The highest marketable yield was recorded in Melka Dima (20 ton/ha) which was about 1.8 times more than the yield of the second ranking cultivar, Melka Eshet and 3.3 times more than Mareko Fana. The highest yield of Melka Dima could be mainly due to higher mean pod weight and relatively larger number of marketable fruits obtained. Legesse et al. (1990) also reported positive correlation between mean pod weight and yield of hot pepper genotypes. There was no significant (P > 0.05) difference in the marketable yield per ha of PBC 600, Mareko Fana and Melka Zala, though the later cultivar had nearly two fold fresh pod yield over the other two varieties. The yield recorded in this study was by far better than the one reported by EARO (2005) for 8 lines that yielded 0.8 to 3.7 ton/ha at Melkassa research center which could be due to intensive management practice in this study as well as very low incidence of diseases and insect damage.

Physiological weight loss

The interaction effects of varieties and storage

Table 2. The interaction effect of storage environment and varieties on the physiological weight loss (%) of pepper fruit during storage period of 28 days at Dire Dawa.

Storage environment/ cultivar treatment	Storage period (days)						
	4	8	12	16	20	24	28
Evaporative cooling							
Melka Dima	2.73^{e}	9.58^{d}	13.34^{c}	17.22^{e}	27.87^{a}	29.77^{a}	35.47^{b}
Melka Eshet	2.80^{e}	8.08^{f}	13.35^{c}	17.52^{e}	18.85^{b}	20.28^{b}	29.07^{c}
Melka Zala	2.49^{f}	8.73^{e}	9.90^{d}	11.40^{g}	14.37^{d}	16.93^{d}	38.94^{a}
Mareko Fana	1.73^{g}	8.59^{e}	10.24^{d}	11.66^{g}	11.76^{e}	15.78^{e}	18.28^{e}
PBC 600	2.81^{e}	7.28^{g}	7.65^{e}	15.56^{f}	16.48^{c}	17.60^{c}	22.70^{d}
Ambient storage							
Melka Dima	7.39^{c}	18.73^{a}	22.50^{a}	30.42^{a}	-	-	-
Melka Eshet	6.17^{d}	14.14^{b}	22.48^{a}	26.17^{c}	-	-	-
Melka Zala	7.51^{c}	13.95^{b}	22.36^{a}	26.19^{c}	-	-	-
Mareko Fana	8.45^{b}	11.55^{c}	19.60^{b}	27.65^{b}	-	-	-
PBC 600	9.21^{a}	13.83^{b}	20.22^{b}	21.24^{d}	-	-	-
Significance	***	***	***	***	***	***	***
SE ±	0.12	0.19	0.22	0.32	0.22	0.27	0.21
LSD (0.05)	0.24	0.40	1.30	0.66	0.72	0.89	0.69
CV (%)	3.88	2.88	2.42	2.67	2.13	2.36	1.26

Means within a column followed by the same letter (s) are not significantly different at P ≤ 0.05; where *** indicate significant difference at P ≤ 0.001.

environment resulted in a significant (P ≤ 0.05) variation in the percent weight loss of the pepper varieties (Table 2). During the initial storage period (day 4), PBC 600 and Mareko Fana stored at ambient condition were found to have the highest percentage of weight loss of 9.2 and 8.5%, respectively. However, Mareko Fana stored in the evaporative cooler showed the lowest percentage weight loss (1.7%) on the same date. On day 8, mean percent weight loss of fruits stored at ambient condition had 70.0% weight loss, than the fruits stored in the evaporative cooler. In the later stage, however, the difference in the weight loss of fruits under the two storage environments tended to narrow down. After day 16, nearly all pepper fruits stored at ambient condition were unmarketable, while those stored in the evaporatively cooled chamber remained marketable up to 28 days. After 28 days of storage in evaporatively cooled chamber, the maximum weight loss was recorded in Melka Zala (38.9%) and minimum loss in Mareko Fana (18.3%).

The higher percentage weight loss in pepper stored at ambient conditions compared with those stored in the evaporative cooler appeared to relate to the RH and temperature surrounding the produce. The evaporative cooler had 28.5 to 40.0% more air humidity as well as 6.0 to 14.0°C less cool than the ambient storage conditions, thereby being capable of reducing excessive moisture loss from the produce. The types of surfaces and underlying tissues of fruit may also have a marked effect on the rate of water loss (Wills et al., 1998) which could be seen as reasons for the differences observed among the varieties.

Quality of most fruits and vegetables is affected by water loss during storage, which depends on the temperature and RH of the storage conditions (Pentzer, 1982). Hardenburg et al. (1986) mentioned that, storage under low temperature is the most efficient method to maintain quality of fruits and vegetables due to its effects on reducing respiration rate, ethylene production, ripening, senescence and rot development. High temperature increases the vapour pressure difference between the fruit and the surrounding, which is the driving potential for faster moisture transfer from the fruit to the surrounding air (Ryall and Pentzer, 1982; Hardenburg et al., 1986; Salunkhe et al., 1991). In the present study, the lower temperature and higher relative humidity maintained by the evaporatively cooled chamber when compared with the ambient condition could be the reason for the low percentage of weight loss possibly through reducing respiration and transpiration rate. Accordingly, the higher physiological weight loss shown at ambient condition can be associated with increased cell wall degradation leading to exposure of cell water for easy evaporation combined with higher membrane, perme-

Table 3. The interaction effect of storage environment and varieties on the moisture content (%) of pepper fruits during 28 days of storage.

Storage environment/ cultivar treatment	Storage period (days)							
	0	4	8	12	16	20	24	28
Evaporative cooling								
Melka Dima	91.74^{a}	91.41^{ab}	91.13^{a}	90.35^{a}	89.84^{a}	88.97^{a}	88.67^{a}	86.40
Melka Eshet	92.53^{a}	92.35^{a}	91.10^{a}	89.68^{a}	89.36^{a}	87.98^{a}	87.65^{ab}	83.99
Melka Zala	91.11^{abc}	89.94^{abc}	90.40^{ab}	85.61^{bc}	87.74^{ab}	88.60^{a}	88.02^{ab}	86.56
Mareko Fana	89.76^{bc}	88.94^{cde}	88.73^{bc}	87.25^{bc}	86.71^{abc}	85.37^{b}	84.80^{bc}	83.43
PBC 600	89.40^{c}	88.09^{de}	87.35^{cd}	86.94^{bc}	86.62^{abc}	85.22^{b}	83.72^{c}	82.83
Ambient storage								
Melka Dima	91.74^{a}	88.20^{cd}	86.11^{d}	86.76^{bc}	85.12^{abc}	-	-	-
Melka Eshet	92.53^{a}	89.53^{bc}	89.34^{ab}	86.72^{ab}	83.84^{bc}	-	-	-
Melka Zala	91.11^{abc}	85.49^{def}	86.64^{cd}	85.64^{c}	84.13^{c}	-	-	-
Mareko Fana	89.76^{bc}	86.67^{def}	84.70^{de}	83.21^{d}	78.85^{d}	-	-	-
PBC 600	89.40^{c}	84.50^{f}	83.64^{e}	84.42^{d}	75.01^{d}	-	-	-
Significance	*	**	**	**	***	**	**	ns
SE ±	0.53	0.30	0.25	0.47	0.52	0.48	1.05	1.06
LSD (0.05)	1.72	1.62	1.74	1.74	2.84	1.55	3.41	3.74
CV (%)	0.53	0.59	0.49	0.93	1.06	0.94	2.09	2.18

Means within a column followed by the same letter (s) are not significantly different at $P \leq 0.05$; ns *, **, *** indicate non significant, significant difference at $P \leq 0.05$, 0.01 or 0.001, respectively. The data from day 16 onwards is meant for the evaporatively cooled storage only.

ability due to faster metabolism and ripening rate at high temperature storage (Dumville and Fry, 2000).

Moisture content

Moisture content of fruits of five hot pepper varieties stored under two storage conditions showed significant variation ($P \leq 0.05$) during the storage periods studied at Dire Dawa (Table 3). At harvest, Melka Eshte and Melka Dima had significantly more moisture content than Mareko Fana and PBC 600, while Melka Zala did not show difference in moisture content from all cultivars.

During the storage period of 4 to 12 days, Melka Eshte and Melka Dima stored in the evaporatively cooled chamber retained more moisture compared with majority of the treatments. At ambient conditions, Melka Eshte fruits had relatively more moisture content compared with the other varieties, under the same storage condition, except on day 16. Significant differences among the cultivars were observed through out the storage period except on the last day of storage. This could be due to differences in fruit tissues of the skin wax contents of cultivars. Maalekuu et al. (2006) noted that, the difference in water loss rate among different genotypes could be attributed to factors such as their cuticlular wax content, difference in cell membrane degradative enzymes and their effects on membrane integrity and membrane lipid composition.

There was a general decreasing trend in the moisture content of the varieties with storage time under both storage conditions. However, the percentage decrease in moisture content was pronounced in fruits stored at ambient condition. This may be due to the ripening process undergo throughout the storage period as ripening of pepper fruit causes changes in the permeability of cell membranes, making them more sensitive to loss of water (Goodwin and Mercer, 1972; Suslow, 2000; Antoniali et al., 2007).

The difference in moisture contents of fruits under the two storage conditions could be attributed to the lower temperature and higher relative humidity in the evaporative cooler than in ambient conditions (Figure 1), which could have reduced the amount and rate of moisture loss. Moreover, the lower temperature in the evaporative cooler could have reduced respiration rate and thus, delayed fruit ripening and subsequently, lowered permeability to moisture loss (Atta-Aly and Brecht, 1995).

Marketability

The interaction effect among cultivars and storage conditions significantly ($P \leq 0.05$) affected percentage of marketable pepper during the storage period (Table 4). On day 4, all pepper stored in the evaporative cooler were marketable, while under the ambient storage there were 1.3 to 5.2% unmarketable fruits in the different cultivars.

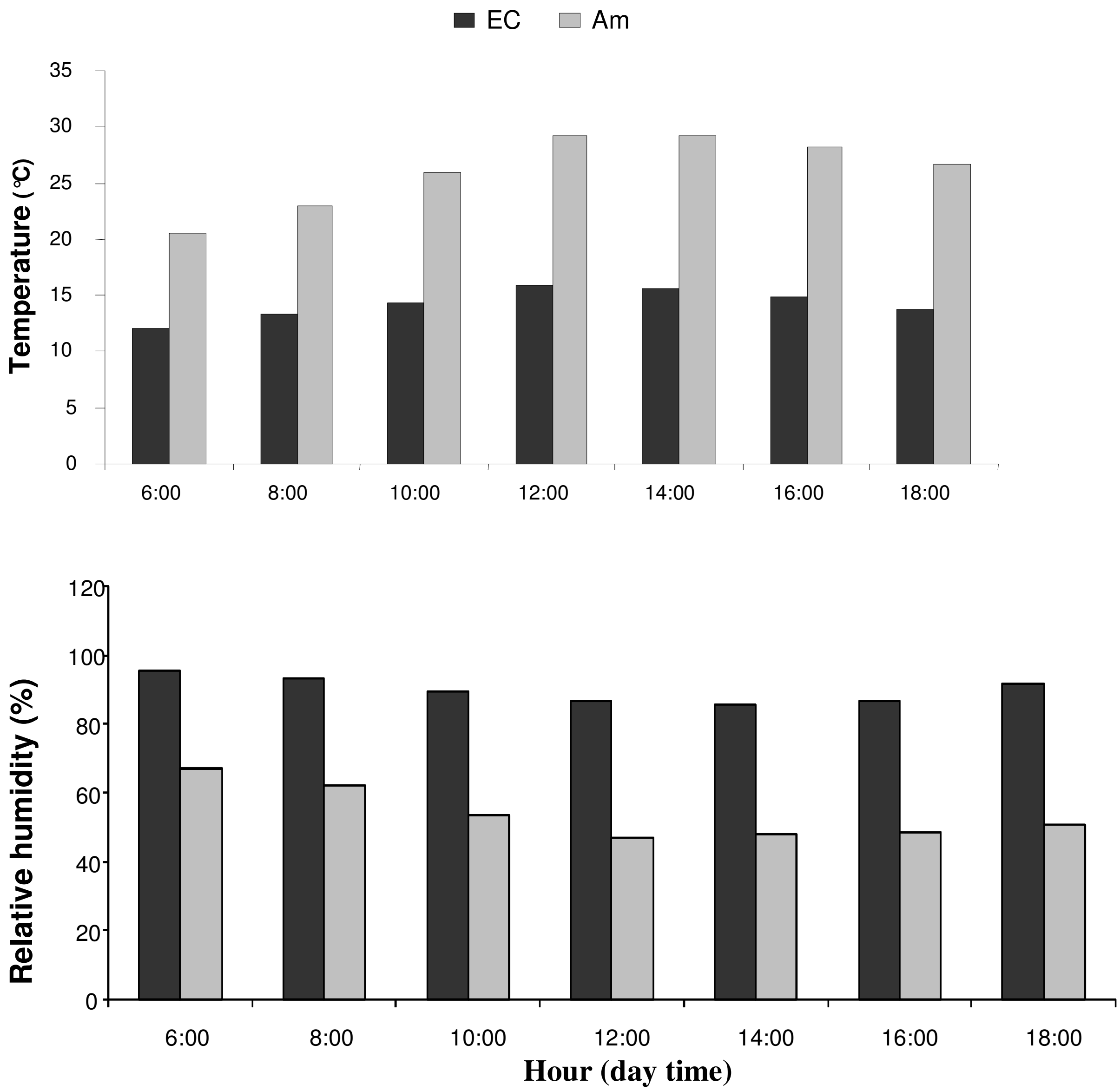

Figure 1. Day time dry-bulb average ambient conditions (Am) and evaporative cooler (EC) temperature and RH during storage of pepper fruit for a period of 28 days.

Marketability of pepper stored at ambient environment was about 98.7% in Mareko Fana that the highest percentage, while Melka Eshet had the lowest percentage (94.8%) of marketable fruits. On day 8, marketability of fruits under the cooler was greater than 96.0%, whereas under ambient condition it dropped below 61.0% in Melka Eshet and 70.0% in Mareko Fana. On day 16, the percentage of marketability of the other pepper in the cooler remained more than 80.0% except in Melka Eshet, while at ambient storage condition, the percentage of marketable pepper fruits in all of the varieties were less than 25.0%.

The extended storage life of pepper fruits stored in the evaporative cooler could be attributed from the increased RH and reduced temperature. From the stated results, it appears that reduced storage temperature as a result of adiabatic cooling of the incoming air has advantageously decreased the rate of pepper fruits deterioration. Storage temperatures have strong positive correlation with the rate at which physiological, biochemical and microbiological changes occur during storage (Ryall and Lipton, 1979; Hardenburg et al., 1986). Thus, the lower the storage temperature the lower would be the rate of deterioration of the stored produce.

In the evaporative cooler, about 82.0% of Mareko Fana fruit remained marketable until three weeks. While in the other varieties percentage of marketability dropped to a level of 62% in Melka Eshte and 77.3% in Melka Zala.

Table 4. The interaction effect of storage environments and varieties on the marketability (%) of pepper fruit during 28 days of storage.

Storage environment/ cultivar treatment	Storage period (days)						
	4	8	12	16	20	24	28
Evaporative cooling							
Melka Dima	100^{a}	97.9^{c}	87.1^{c}	80.2^{c}	70.0^{d}	46.0^{d}	19.3^{d}
Melka Eshet	100^{a}	96.6^{d}	83.8^{d}	75.2^{d}	62.0^{e}	34.0^{e}	9.3^{e}
Melka Zala	100^{a}	98.4^{b}	89.1^{b}	82.7^{b}	77.3^{b}	56.0^{b}	30.7^{b}
Mareko Fana	100^{a}	98.9^{a}	91.8^{a}	87.3^{a}	82.2^{a}	59.8^{a}	37.6^{a}
PBC 600	100^{a}	96.3^{d}	87.8^{c}	80.7^{c}	74.0^{c}	51.6^{c}	23.3^{c}
Ambient storage							
Melka Dima	95.6^{e}	65.3^{h}	29.3^{h}	16.0^{h}	-	-	-
Melka Eshet	94.8^{f}	60.7^{i}	20.0^{i}	12.7^{i}	-	-	-
Melka Zala	96.9^{c}	67.1^{f}	33.3^{f}	19.8^{f}	-	-	-
Mareko Fana	98.7^{b}	69.6^{e}	39.3^{e}	24.0^{e}	-	-	-
PBC 600	96.5^{d}	65.9^{g}	31.3^{g}	18.0^{g}	-	-	-
Significance	***	***	***	***	***	***	***
SE ±	0.08	0.19	0.61	0.38	0.38	0.26	0.55
LSD (0.05)	0.18	0.40	1.27	0.80	1.23	0.86	1.80
CV (%)	0.15	0.41	1.77	1.33	0.90	0.92	3.99

Means within a column followed by the same letter (s) are not significantly different at P ≤ 0.05, *** indicate significant difference at P ≤ 0.001. The data from day 16 onwards is meant for the evaporatively cooled storage.

Overall, Mareko Fana fruits stored in the evaporative cooler performed better than the other varieties and most of them stayed marketable, while Melka Eshte was the least. The result showed that, maintaining lower temperature and higher RH in the storage combined with selecting cultivars having long shelf life could improve marketability of pepper for a relatively longer period.

A comparison based on the overall mean marketable pepper fruits after two weeks (day 16) clearly show that, pepper fruit marketability could be increased nearly four-fold using the evaporative cooler storage system, compared with the ambient condition. This could be mainly due to the fact that, low storage temperature reduces the rate of respiration and physiological activity leading to retarded senescence of fruit in storage (Pinto et al., 2004). Moreover, the increased RH in the cooler reduces shrinkage of fruits through moisture loss. Hardinsburg et al. (1986) reported that the effective method of maintaining quality and controlling decay of peppers is by a rapid cooling after harvest followed by storage at low temperature with a high RH.

The visual appearance and marketability of pepper fruit stored in the evaporative cooler remained fresh and shiny with good pod color for a reasonable period of storage time. Shriveling and discoloration at ambient temperature and rotting in pepper fruits stored in the evaporative cooler storage were major causes for a decline in percentage of marketability, with time. This result agrees with previous reports that showed significant improvement in the shelf life of fruits and vegetables stored in evaporative cooler, in which losses associated with decay were also observed (Workneh and Woldetsadik, 2001). Although, storing pepper varieties in the evaporative cooler extend their shelf life, it was hardly possible to control loss due to fruits decay. This is due to the fact that evaporative cooler, although reduced the storage temperature, was not able to maintain the temperature to optimum level for storing pepper fruits for an extended period. Therefore, it appears that a combination of disinfection, modified atmosphere packaging and storage in evaporative cooler might improve the storage life of green pepper and other perishable produce.

Conclusions

Melka Zala, PBC 600 and Mareko Fana pepper varieties grown at Dire Dawa produced 58.1 to 59.6 cm tall plants with no significant difference among them, while the cultivar Melka Eshet (42.7 cm) had the shortest plants. The tall varieties also tended to have more number of branches. Melka Zala required about 150 days reaching the first harvest, while Melka Dima was found to be the earliest cultivar, with a maturity date difference of 25 days with the late cultivar. The remaining three varieties had maturity date in the range of 142.3 to 147.7 days. The highest numbers of total and marketable fruits were recorded in PBC 600 and Mareko Fana, respectively, with a significant difference in marketable fruit number among them. The lowest total and marketable fruit numbers were recorded in Melka Eshet. Numbers of marketable fruits ranged from 14.7 in Melka Eshet to 25 in PBC 600. The lowest mean pod weight was recorded in PBC 600 which was about 61.0% less than in Melka Dima that produced fruits of the bigger size. Melka Dima also produced the highest marketable yield which was 77.0 and 114.0% over the second and third ranking Melka Eshet and Melka Zala varieties, respectively and 323.0% more than the lowest yielder PBC 600 cultivar that gave 4.7 ton/ha marketable yield. The highest weight loss was recorded in Melka Dima stored at ambient condition, while lowest weight loss was observed in Mareko Fana stored in the evaporative cooler. The highest and lowest fruit moisture contents were recorded in Melka Eshet and PBC 600, respectively, throughout the storage period. After 12 days of storage in the evaporative cooler, Mareko Fana had more than 90.0% of the fruits in a marketable condition, while in the remaining varieties marketability dropped to 84.0 and 88.0%. After 16 days of storage, nearly all pepper fruits stored at ambient condition were found to be unmarketable, while those stored in the evaporative cooler chamber were kept up to 28 days.

REFERENCES

Acedo AL (1997). Ripening and disease control during evaporative cooling storage of tomatoes. J. Trop. Sci. 37: 209-213.

Ado SG, Samarawira I, Olarewaju JD (1987). Evaluation of local accession of pepper (*Capsicum annum*) at Samaru, Nigeria. Capsicum Newslett. 17-18.

Agonafir Y (1991). Economics of horticultural production in Ethiopia. Acta Hortic. 270: 15-19.

Amjad M, Iqbal J, Iqbal Q, Nawaz A, Ahmad T, Rees D (2010). Effect of packaging material and different storage regimes on shelf life and biochemical composition of green hot pepper fruits. Acta Hortic. 876: 227-234.

Antoniali S, Leal PAM, de Magalhães AM, Fuziki RT, Sanches J (2007). Physico-chemical characterization of 'Zarco HS' yellow bell pepper for different ripeness stages. Sci. Agric. 64:19-22.

Atta-Aly MA, Brecht JK (1995). Effect of postharvest high temperature on tomato fruit ripening and quality. Proceedings of the International Symposium "Postharvest Physiology, Pathology and Technologies for Horticultural Commodities: Recent Advances" A. pp. 250-256.

Bakker JC, Van Uffelen JAM (1988). The effect of diurnal temperature regimes on growth and yield of glasshouse sweet pepper. Nether. J. Agric. Sci. 36: 201–208.

Belay A (2002). Factors influencing loan repayment performance of rural women in eastern Ethiopia: The case of Dire Dawa area. An M.Sc. Thesis presented to the School of Graduate Studies of Alemaya University. pp 1-102.

Bosland PW (1996). *Capsicum*: Innovative uses of an ancient crop. In: Janic J (ed.), progress in new crops. ASHS, press, Arligton, VA. pp 479- 487

Chakraverty A, Mujumdar SA, Raghavan SG, Ramaswamy SH (2003). Handbook of Postharvest Technology. Cereals, fruits, Vegetables Tea and Spices. Marcel. Deker, Inc., New York. Basel. p. 521.

Cochran HL (1964). Changes in pH of the pimiento during maturation. Proc Am. Soc. Hort. Sci. 84: 409-411.

Dumville JC, Fry SC (2000). Uronic acid-containing oligosaccharins: Their biosynthesis, degradation and signaling roles in non-diseased plant tissues. Plant Physiol. Biochem. 38: 125-140.

EARO (2004). Ethiopian Agricultural Research Organization 2002/03 Annual report, EARO. Addis Ababa.

Engles JMM (1984). *Capsicum*, an Improtant Spice in Ethiopia. *Capsicum* Newslett. 3: 19-25.

Erickson AN, Markhart AH (1997). Development and abortion of flowers in *capsicum annum* exposed to high temperature. Hort. Technol. 7: p. 8.

Rylski I, Spigelman M (1986). Fruits and tree nuts, 2nd edition, AVI, Westport CT. Effects of shading on plant development, yield and fruit quality of sweet pepper grown under conditions of high temperature and radiation. Sci. Hortic. 29: 31-35.

Geleta L (1998). Genetic Variability and association for yield, quality and other traits of hot pepper *(Capsicum* spp.). An M.Sc Thesis presented to the School of Graduate Studies of Alemaya University.

Getenit H, Workneh TS, Woldetsdik K (2008). The effect of cultivar, maturity stage and storage environment on quality of tomatoes. J. Food Eng 87: 467-498.

Godfrey SA, Turuwork WA, Tadelle A (1985). Review of Tomato Research in Ethiopia and Proposal for future Research and Development direction. In: Godfrey-Sam-Aggrey and Bereke Tsehi (eds.). Proceedings of the First Ethiopian Horticultural Workshop. pp. 236-249.

Gomez KA, Gomez AA (1988). Statistical Procedures for Agricultural Research. John Willey and Sons, New York. p. 390

Goodwin TW, Mercer EI (1972). Introduction to Plant Biochemistry. Pergamon Press, Oxford. p. 359.

Hardenburg RE, Watada AE, Wang CY (1986). The commercial storage of fruits, vegetables, florist, and nursery stocks. Agriculture Handbook, Washington. 66: 1-130.

Kebede E (1991). Processing of horticultural produce in Ethiopia. Acta Hortic. 270: 301-311.

Legesse G, Zelleke A, Bejiga G (1999). Character association and path analysis of yield and its components in hot pepper (*Capsicum annuum* L.). Acta Agronomica Hungarica, 47: 391-396.

Lemma D, Edward H, Terefe B, Berga L, Seifu G (1994). Horticultural research: past present and future trends. Procceedings of the second national horticultural workshop of Ethiopia. IAR/FAO, Addis Ababa.

Maalekuu K, Elkind Y, Frenkel AL, Lurie S, Fallik E (2006). The relationship between water loss, lipid content, membrane integrity and *LOX* activity in ripe pepper fruit after storage. Postharvest Biol. Technol. 42: 248- 255.

Mohammed M, Wilson LA, Pi LA, Gomes P (1992). Postharvest losses and quality changes in hot peppers (*Capsicum frutescens* L.) in the roadside marketing system in Trinidad. Trop. Agric. 69: 333-340.

Mohammed M, Wilson LA, Gomes PL (1999). Postharvest sensory and physiochemical attributes of processing and non-processing tomato cultivar. J. Food Qual. 22: 167-182.

Pinto AC, Alues RE, Pereira EC (2004). Efficiency of different heat treatment procedures in controlling disease of mango fruits. Proceedings of the seventh international mango symposium. Acta Hortic. 645: 551-553.

Ryall AL, Lipton WJ (1979). Vegetables as living products. Respiration and heat production . Handling , transportation and storage of fruits, 2nd ed., The AVI Publishing Company, Westport. Vol. 1. p. 421.

Ryall AL, Pentzer WT (1982). Handling, transportation and storage of fruits and vegetables. Vol. 2.

Salunkhe DK, Bolin HR, Reddy NR (1991). Storage, Processing, and Nutritional Quality of Fruits and Vegetables. 2nd ed. Fresh Fruits and Vegetables. Vol. I p. 365.

Suslow T (2000). Bell peppers hit with late season losses to decay. Perishable Handling Quart. Issu. 101: p. 1.

Tadesse F (1991). Postharvest losses of fruit and vegetable in horticultural state farms, Ethiopia. Acta Hortic. 270: 261-270.

Thompson JF, Mitchell FG, Runsey TR, Kasmire RF, Crisosto CH (1998). Commercial cooling of fruits, vegetables and flowers, UC Davis, USA, DANR publication, No 21567: 61-68.

Wills R, Glasson EM, Graham D, Joyce D (1998). Postharvest. An introduction to the physiology and handling of fruit, vegetables and ornamentals. 4thed. UNSW Press. p. 21

Workneh TS, Woldetsadik K (2001). Natural ventilation evaporative cooling of Mango. J. Agri. Biotech. Environ. 2: 1-2