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Effects of disinfection, packaging and evaporatively cooled storage on sugar content of mango

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The present investigation was undertaken to evaluate the effect of post-harvest disinfection, packaging, evaporative cooling storage and their combined effect on the changes in sugar content of mango (*Mangifera indica* L.). The experiment was laid out in a factorial combination of disinfection, packaging and storage in a randomized complete block design with three replications. The mangoes were periodically analyzed for reducing sugar and total sugar. Non-reducing sugar was computed from the difference between experimental reducing and total sugars. Storage conditions significantly (P ≤ 0.01) affected sugar content in mangoes. Storage at ambient conditions with higher temperature and lower relative humidity as compared to the evaporatively cooled storage resulted in rapid deterioration in sugar content of the mangoes. During the storage period, packaging generally maintained higher (P ≤ 0.01) levels of reducing sugar, non-reducing sugar and total sugar. Similarly, disinfection treatment significantly (P ≤ 0.01) affected the changes in reducing, non-reducing and total sugars of mangoes during storage. Two-way interactions were significant (P ≤ 0.01) in terms of the changes in sugar content of mangoes. The benefits of the combined effect of post-harvest treatments on mangoes included maintenance of high reducing sugar, non-reducing sugar and total sugar.

Key words: Mango, total sugar, reducing sugar, evaporative cooling, disinfection, packaging.

INTRODUCTION

Growing and marketing of fresh produce are complicated by post-harvest losses in quantity and quality between harvest and consumption (Mitra and Baldwin, 1997; Seyoum, 2002). The quality of fresh fruits depends on post-harvest handling during harvesting, transportation and storage (Haidar and Demisse, 1999). Compared with several temperate fruits, tropical and subtropical fruits such as mango present greater problems in storage and transportation because of their perishable nature (Mitra and Baldwin, 1997). Kader (1992) estimated the extent of post-harvest losses in fresh fruit and vegetables at 5 - 25% in developed countries and 20 - 50% in developing countries. In Ethiopia, post-harvest losses of horticultural commodities in state farms and peasant sectors are estimated to be 25-35%, caused by a combination of several factors (Fekadu, 1991). This high loss was attributed partly to lack of packaging, storage facilities, poor means of transportation and handling. There is no proper means of post-harvest handling of mangoes at retailer and wholesaler levels. Even though the country is experiencing such a huge loss of fruit, very little emphasis has been given to post-harvest handling of perishable produce (Tadesse, 1991).

The perishability of mango emanates from the susceptible nature of the crop to post-harvest problems during prolonged storage (Prusky et al., 2001). Several mango post-harvest techniques have been developed for controlling diseases and insects, and for protection against injury during packaging and storage (Pinto et al., 2004). Many physical and chemical treatments have been used for control of post-harvest losses in mango (Johnson et al., 1997). Low temperature handling and storage are the most important physical method of post-harvest loss control (Seyoum and Woldetsdik, 2004). Temperature of the surrounding air and produce can be reduced by forced

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air cooling, hydrocooling, vacuum cooling, and adiabatic cooling (Thompson et al., 1998). In addition, mechanical refrigeration, controlled atmospheres, hypobaric storage, and other sophisticated techniques are used in developed countries to extend shelf life and minimize post-harvest losses in perishable produce. The latter techniques are capital intensive and the required manpower is lacking or inadequate in most developing countries. Moreover, these cooling methods, except adiabatic cooling, are expensive for small scale peasant farmers, retailers and wholesalers, as they require electric power. Low temperature and high relative humidity can be achieved by using less expensive methods of evaporative cooling (Seyoum and Woldetsadik, 2000; Seyoum and Woldetsadik, 2004). Low temperature reduces physiological and biochemical changes and maintains the chemical composition of mangoes. Favorable temperature that can be achieved by using less expensive methods of evaporative cooling could be combined with other appropriate preservation operations such as hot water and disinfection using hypochlorite. Hot water immersion has a number of advantages which include short treatment time, reliable and accurate monitoring of fruit temperature with the benefits of killing surface decay organisms and cleaning the fruit of plant exudates (Jordan, 1993; Sharp, 1994). Appropriate post-harvest treatments of fruits can reduce enzymatic activities and post-harvest decay problems eventually increasing the shelf life of the fruits (Waskar et al., 1999). A few chemicals such as chlorine and sulphur-dioxide are considered to be true fungicide (Johnson et al., 1997). For several reasons such as the availability of chlorinated solutions and cost, chlorine disinfections seem to be more suitable to developing countries (Seyoum, 2002). Although several chemicals and biological products are available in the market, their success remains limited due to variations in their effectiveness and lack of experience on how to adopt them to the commercial setting (Seyoum, 2002). For developing countries like Ethiopia, use of chlorinated water dipping treatment could be the less expensive and easily applicable. Thus, there is a need to develop affordable combined post-harvest treatments that might minimize the post-harvest loss of mangoes under Ethiopian conditions. However, the effect of this low cost appropriate preservation technology on the changes in chemical composition like sugars, a substrate in the respiration process, has to be investigated. Therefore, the objective of this study was to evaluate the changes in sugar content of mangoes subjected to combined post-harvest treatments such as disinfection, packaging and evaporatively cooled storage.

MATERIALS AND METHODS

Sample preparation

Green mature mangoes were obtained from an orchard in Bisidimo Leprosy Rehabilitation Hospital, Eastern Ethiopia. Harvesting was carried out manually. Plastic containers were used for transporting the fruits to the experiment site, immediately after harvest. Uniform mangoes were taken immediately after sorting. The mangoes were washed with tap water to remove field heat, soil particles, and to reduce microbial populations on the surface.

A factorial experiment with two storage treatments, two types of packaging and five disinfection treatments arranged in a completely randomized design with three replications were used in the study. The disinfection treatments included dipping in chlorinated water, hot water (46°C and 52°C), tap water (23°C) and control which were sub-divided to package or held unpackaged and stored under ambient or evaporatively cooled storage. A total amount of 300 kg mangoes were in the study. Mangoes were packaged or unpackaged in 1 kg unit. From the 1 kg unit per treatment, five fruit samples were randomly taken for the destructive analysis of reducing and total sugars.

For the chlorinated water dipping treatment, tap water was adjusted to 100 □g ml^{-1} total chlorine with standard grade sodium hypochlorite (5% NaOCl) in which mango was dipped for 20 min (Nunes and Emond, 1999; Seyoum et al., 2003). The total chlorine was determined using a test kit from Hach (Model CN-66, USA). The temperature was maintained at 4°C during the measurements of total chlorine. A 20 min dipping time in 100 µg ml^{-1} chlorine supplemented water solutions was selected, as this was reported to be the optimum effective concentration and dipping time without significant effect on the overall quality of fruit and vegetables (Nunes and Emond, 1999). The hot water dipping treatments included dipping mangoes in hot water at 46 and 52°C for five min. Dipping fruits in tap water (23°C) for 20 min was used as control treatment.

After the disinfection treatment, sample mangoes were surface dried and divided in to two sub-samples for packaging in polyethylene bag or unpackaged treatments. The packaging material used was low-density polyethylene film (Xtend® film, patent NO. 6190710, Stepac, A. Ltd, Israel). The packaged fruits were sub-divided into two for storage in the cooler and at ambient temperature. Similarly the unpackaged sample mangoes were divided into two lots for storage in the evaporative cooler and at ambient temperature.

Evaporative cooler

The evaporatively cooled storage used in this study had been described in the earlier reports (Seyoum and Woldetsadik, 2004). The evaporative cooling chamber maintained lower temperature and higher humidity compared to the ambient conditions. The evaporative cooler maintained the temperature between 14.3 and 19.2°C and relative humidity between 70 and 82.4% during the storage period. Earlier, the evaporative cooler maintained the temperature between 14.4 and 23.5°C and relative humidity between 73 and 92% during storage periods (Seyoum, 2002). The ambient dry bulb air temperature and relative humidity varied from 23–43°C and 16 – 79% during the storage period, respectively. The average differences in dry bulb temperature between ambient and inside the cooler was 10.7°C, with an average difference in relative humidity of 36.7% during the storage period.

Data collection

On each sampling data, a sample of mangoes was randomly taken from each treatment for quality analyses. On each sampling data, one unit of package fruits or a sample of 1 kg mangoes from packaged and unpackaged fruits in each treatment was randomly taken for assessment. A new package or unpackaged fruit sample was taken each time. Data were recorded on 3, 7, 14, 21, and 28 days of storage.

Sugar analysis

Reducing and total sugars were estimated by using the calorimetric methods of Somogyi et al. (1945), as presented by Seyoum (2002). Clear juice (10 ml) was added to 15 ml of 80% ethanol, mixed and heated in a boiling water bath for 30 min. After extraction, 1 ml of saturated lead acetate ($Pb(CH_3COO)_2.3H_2O$) and 1.5 ml of saturated sodium phosphate ($NaHPO_4$) were added and the contents were mixed by gentle shaking. After filtration, the extract was made up to 50 ml with distilled water. An aliquot of 1 ml extract was diluted to 25 ml with 1 ml copper reagent in a test tube and heated for 20 min in a boiling water bath. After heating, the contents were cooled under running tap water without shaking. Arsenomolybdate color reagent (1 ml) was added, mixed, made up to 10 ml with distilled water and left for about 10 min to allow color development, after which the absorbance was determined by a spectrophotometer at 540 nm in a Jenway model 6100 spectrophotometer. For total sugar determination, sugar was first hydrolyzed with 1 N HCl by heating at 70°C for 30 min. After hydrolysis, total sugar was determined following the same procedure employed for the reducing sugar. A blank was prepared using distilled water.

Statistical analysis

Significance tests were made by analysis of variance (ANOVA) for randomized complete block design with factorial arrangement according to Gomez and Gomez (1984). ANOVA was carried out with an MSTAT-C soft ware package (MSTAT, Michigan State University, East Lansing, USA). Comparisons of the treatment means were done using Duncan's multiple range test (Duncan, 1955).

RESULTS AND DISCUSSION

Reducing sugar

The reducing sugar varied from 1.42 - 6.08 g 100 g^{-1} of fresh weight at evaporatively cooled storage conditions and 0.82 and 5.54 g 100 g^{-1} of fresh weight at ambient condition (Table 1). Reducing sugar content showed a high degree of variability during the storage. It was found to be higher in mango fruits stored at ambient temperature on the 3rd and 7th day of storage compared to the mango fruits stored in evaporatively cooled storage (Table 1); however, the latter had higher levels of reducing sugars on day 14. Earlier, it has been reported that reduced temperature in evaporatively cooled storage reduces fruit metabolism, particularly respiratory activity, delaying the ripening process and increasing fruit shelf life up to two weeks (Koksal, 1989). Reducing sugars such as glucose are the main substrates in the respiration process to produce energy required in the metabolism of fruit (Seyoum, 2002), and at relatively higher temperature storage utilization of reducing sugars is usually high.

During the storage period, reducing sugars showed a general trend of an initial increase followed by a deceasing pattern. The increase in reducing sugars could be due to the break down of polysaccharides into water soluble sugar. However, as storage time advances, reducing sugar content declines. Similar changes were also observed by Wiley (1994). Other findings also indicated that starch is completely hydrolysed into sugar such as glucose, fructose and sucrose as ripening progresses (Mattoo et al., 1975).

Packaging had a significant ($P \leq 0.01$) effect on the reducing sugar of mango fruits during the storage period (Table 1). The packaging seemed to maintain higher reducing sugar contents in mango fruits than unpackaged mango fruits except on day 3. Packaged mango fruits had 16.62% more reducing sugar compared with unpackaged mango fruits during the 28 days of storage (Table 1). Previous findings indicated that the beneficial effect of packaging is increasing shelf life of perishable products, partially due to the decrease in O_2 concentration and the increase in CO_2 levels in the packaging head space that lead to a reduction in enzymatic activities responsible for quality deterioration (Ben-Yehoshua, 1985). Burg and Burg (1967) had shown that the CO_2 level is a competitive inhibitor of ethylene production during storage and metabolic activities are reduced through an increase of CO_2 levels in the microatmosphere inside the package. Low O_2 and high CO_2 levels in the heads space reduce respiration and the production of ethylene during storage in passive modified atmosphere packaging (MAP), which in turn reduces physiological, chemical and biochemical changes responsible for the fruits quality deterioration, and would prolong the shelf life of produce (Agar and Streif, 1996; Seyoum, 2002).

Disinfecting treatment significantly ($P \leq 0.01$) affected the content of reducing sugar throughout the storage period. After 28 days of storage, the reducing sugar level remained to be lower in control mango fruits compared to the mango fruits dipped in chlorinated water, hot water (46 and 52^{o}C) and tap water and stored in cooled storage (Table 1). Similarly, the lowest reducing sugar content was found in unpackaged mangoes after 14 days at ambient conditions.

The interaction of disinfecting and packaging was significant in their effects on reducing sugar content of mango fruits. The interaction between disinfection and packaging was highly significant ($P \leq 0.001$). Likewise, the two way interaction between packaging and storage environment was significant ($P \leq 0.01$).

Storage conditions influenced the effectiveness of post-harvest treatments on the changes in reducing sugar of mango fruits during storage, which was demonstrated by the interactive effect of storage condition with the post-harvest treatments. The reducing sugar content of the mangoes was affected ($P \leq 0.01$) by the combined effect of disinfection, packaging and storage condition treatments which exhibited a statistically significant ($P \leq 0.01$) interaction (Table 1). The result showed that combining post-harvest treatments highly maintained the reducing sugar contents and hence improved the nutritional quality of mangoes.

Non-reducing sugar

The non-reducing sugar contents varied between 0.02 -

Table 1. Effects of post-harvest disinfection, packaging and storage treatments on reducing sugar content of mangoes over a storage period of 28 days.

Treatment	Reducing sugar (g 100 g^{-1})				
	3 days	7 days	14 days	21 days	28 days
Packaged, cool storage					
NaOCl	1.48^{efg}	4.02^{cd}	4.82^{c}	5.58^{b}	3.35^{d}
H_2O, 52°C	1.46^{fghi}	2.43^{lm}	6.08^{a}	5.85^{a}	4.28^{b}
H_2O, 46°C	1.44^{ghi}	2.92^{hij}	5.98^{a}	5.25^{c}	4.58^{a}
H_2O, 23°C	1.45^{fghi}	4.06^{c}	4.76^{c}	5.32^{bc}	4.27^{b}
Control	1.45^{fghi}	3.01^{hi}	4.71^{c}	3.76^{f}	2.44^{f}
Unpackaged, cool storage					
NaOCl	1.45^{fghi}	2.39^{mn}	4.26^{de}	5.40^{bc}	3.43^{d}
H_2O, 52°C	1.80^{c}	2.83^{hijk}	3.15^{hij}	3.75^{f}	3.40^{d}
H_2O, 46°C	1.43^{h}	2.70^{jkl}	3.96^{ef}	4.16^{e}	2.74^{e}
H_2O, 23°C	1.83^{c}	3.76^{de}	5.54^{b}	4.54^{d}	3.74^{c}
Control	1.47^{fgh}	2.80^{ijk}	3.65^{g}	2.69^{g}	2.49^{f}
Packaged, ambient storage					
NaOCl	1.44^{fghi}	5.54^{a}	5.42^{b}	-	-
H_2O, 52°C	2.05^{b}	3.44^{f}	3.23^{hi}	-	-
H_2O, 46°C	1.43^{h}	3.60^{ef}	3.53^{gh}	-	-
H_2O, 23°C	1.45^{fghi}	3.04^{hi}	2.76^{j}	-	-
Control	1.50^{ef}	4.68^{b}	4.47^{cd}	-	-
Unpackaged, ambient storage					
NaOCl	1.60^{d}	3.34^{fg}	3.05^{ij}	-	-
H_2O, 52°C	1.63^{d}	2.59^{klm}	1.88^{k}	-	-
H_2O, 46°C	2.02^{b}	3.12^{gl}	2.82^{ij}	-	-
H_2O, 23°C	2.63^{a}	3.49^{ef}	3.06^{ij}	-	-
Control	1.52^{e}	2.11^{n}	0.82^{l}	-	-
C.V	1.27	5.00	5.94	3.18	2.87
S.E	0.02	0.09	0.13	0.09	0.06
Significance					
A	**	**	**	**	***
B	**	**	**	***	**
C	***	***	***	-	-
A x B	**	***	**	***	**
A x C	**	**	**	-	-
B x C	**	***	*	-	-
A x B x C	**	**	**	-	-

Initial (0 day) reducing sugar was 1.42 g 100 g^{-1} and the data from day 21 onwards are mean valves for the evaporatively cooled storage only.
A, Disinfection; B, packaging; C, storage.
*, **, *** indicate significant difference at P ≤ 0.05, 0.01or 0.001, respectively.
Means within the same column followed by a common letter are not significantly different at P ≤ 0.05 (DMRT).

6.83 g 100 g^{-1} and the effect of storage environment was found to be significant (Table 2). It is evident from the data presented in Table 2 that the non-reducing sugar content of mango fruits was maintained higher in the evaporative cooler than in mango fruits stored at ambient conditions, except on day 3. This may be attributed to the evaporative cooling chamber's ability to lower the temperature and raise the relative humidity compared to the ambient storage, which is in agreement with the previous finding (Seyoum, 2002). The importance of the lower temperature is that it retards aging through reduced respiration rate and hence reduce rate of hydrolysis of starch in similar sugar.

An initial rise in non-reducing sugar of mango fruits and fall afterwards were observed under both storage conditions. This indicated that during ripening of fruits,

Table 2. Effects of post-harvest disinfection, packaging and storage treatments in the non reducing sugar of mangoes over a storage period of 28 day.

Treatment	Non reducing sugar (g 100 g^{-1})				
	3 days	7 days	14 days	21 days	28 days
Packaged, cool storage					
NaOCl	1.68^{f}	5.67^{e}	3.08^{g}	0.84^{e}	2.15^{b}
H_2O, 52°C	2.00^{c}	6.70^{ab}	2.76^{hi}	0.83^{e}	0.57^{d}
H_2O, 46°C	2.72^{c}	3.86^{ij}	1.58^{k}	0.49^{f}	0.85^{c}
H_2O, 23°C	1.10^{gh}	4.69^{fg}	3.89^{e}	0.21^{g}	0.16^{g}
Control	2.30^{de}	4.38^{ghi}	1.78^{k}	1.62^{c}	0.18^{fg}
Unpackaged, cool storage					
NaOCl	0.87^{h}	6.83^{a}	3.49^{f}	0.24^{g}	0.92^{c}
H_2O, 52°C	1.23^{g}	6.30^{bcd}	5.08^{b}	2.37^{a}	0.40^{e}
H_2O, 46°C	1.62^{f}	5.10^{f}	3.53^{f}	1.18^{d}	2.50^{a}
H_2O, 23°C	1.18^{g}	5.76^{e}	3.79^{e}	1.22^{d}	0.65^{d}
Control	0.85^{h}	6.03^{cde}	1.30^{l}	1.95^{b}	0.26^{f}
Packaged, ambient storage					
NaOCl	1.70^{f}	0.95^{k}	0.11^{n}	-	-
H_2O, 52°C	2.02^{e}	4.08^{hi}	2.41^{j}	-	-
H_2O, 46°C	2.91^{bc}	4.01^{hij}	2.89^{gh}	-	-
H_2O, 23°C	2.42^{d}	3.51^{j}	2.61^{ij}	-	-
Control	3.16^{b}	4.31^{ghi}	0.98^{m}	-	-
Unpackaged, ambient storage					
NaOCl	2.75^{c}	5.85^{de}	4.50^{c}	-	-
H_2O, 52°C	3.76^{a}	5.10^{f}	4.22^{d}	-	-
H_2O, 46°C	2.03^{e}	5.03^{f}	2.90^{gh}	-	-
H_2O, 23°C	1.63^{f}	4.45^{gh}	3.80^{e}	-	-
Control	3.01^{b}	6.41^{abc}	5.98^{a}	-	-
C.V	8.48	5.91	13.24	9.23	6.77
S.E	0.10	0.17	0.08	0.07	0.03
Significance					
A	**	***	**	*	**
B	**	**	**	***	**
C	***	***	***	-	-
A x B	**	***	***	***	**
A x C	**	**	**	-	-
B x C	**	**	*	-	-
A x B x C	***	***	***	-	-

Initial (0 day) reducing sugar was 1.42 g 100 g^{-1} and the data from day 21 onwards are mean values for the EC only.
A, Disinfection; B, packaging; C, storage.
*, **, *** indicate significant difference at P ≤ 0.05, 0.01 or 0.001, respectively.
Means within the same column followed by a common letter are not significantly different at P ≤ 0.05 (DMRT).

carbohydrates undergo metabolic transformations, both qualitatively and quantitatively. Starch is completely hydrolysed to glucose, fructose and sucrose as ripening progresses (Mattoo et al., 1975). Hulume (1971) reported that after prolonged storage, all sugars decrease but mango shows higher sucrose concentration and smaller proportion of reducing sugars as starch is hydrolyzed; later in storage, sucrose tends to disappear to be replaced by equal amount of reducing sugars.

Similarly, packaging had a significant effect on the content of non-reducing sugar during the storage period (Table 2). Disinfections had a significant effect on the non-reducing content of mango fruits. However, the importance of the treatments was found to be inconsistent during the storage period. The highest non-reducing sugar content was observed in mango fruits dipped in hot

water (46°C) and the lowest in those mango fruits dipped in tap water on day 3. The non-reducing sugar content was found to be higher on day 7 in mango fruits dipped in hot water (52°C) and on day 14 in mango fruits dipped in hot water at 52°C and tap water. On day 21 the controlled mango fruits were the highest non-reducing sugar. On the other hand, after 28 days of storage the hot water at 46°C treated mango fruits had the highest non-reducing sugar content than others treatments. Previous finding also indicated that some heat treatments could also delay or inhibits ripening in certain mango varieties (Mitcham and McDonald, 1997), leads to better maintenance of non-reducing sugar during storage.

The two way interaction between disinfections with packaging, disinfections with storage environment and packaging with storage temperature showed significant ($P \leq 0.01$) difference in the non-reducing sugar content of mangoes (Table 2). The three way interaction between disinfection, packaging and storage conditions showed highly significant ($P \leq 0.001$) effect on the non-reducing sugar content of mango fruits during the storage period. This data clearly indicated that proper post-harvest treatment combination had positive effect on maintaining better chemical quality of mangoes during storage.

Total sugar

The total sugar varied between 2.25 and 9.69 g 100 g^{-1} of fresh weight (Table 3). Mango fruits exhibited increasing level of total sugars up to 7 day of storage and followed by decreasing trend afterwards. Total sugar of mangoes on 3rd day was higher in treatments stored at ambient condition while on 7th and 14th days mango fruits stored in the evaporative cooler had higher total sugar contents. This could be associated with the higher rates of metabolism of substrate under ambient temperature, which was in agreement with the previous report by Koksal (1989).

Storage conditions were the most important factor affecting ($P \leq 0.001$) the post-harvest quality and shelf life of mango fruits. This indicates that lowering the storage temperature reduces respiration and senescence while high temperature storage hastens the senescence of mango fruits. Wang (1989) suggested that low temperature storage is the most effective method for persevering the chemical composition of most perishable horticultural commodities because it retards respiration, delays ripening besides imposing other undesirable metabolic changes.

Packaging seemed to have significant effects on the total sugar content of mango fruits (Table 3). It maintained higher total sugar contents in mango fruits during the later parts of the storage period than unpackaged mango fruits while on day 7 and 14 the latter had higher levels of total sugar contents (Table 3). Packaging increases the shelf life of fruits and vegetables partly due to the decreased O_2 and the increased CO_2 concentration resulting in a reduction in enzymatic activities responsible for quality deterioration (Ben-Yehoshua, 1985). Then, if the respiration rate of mango fruits is reduced due to the effects of lower level of O_2 and higher concentration of CO_2, less sugar is normally utilized and thus maintained better during storage. Several researchers also demonstrated the effects of lower concentration of O_2 and higher level of CO_2 on the maintenance of water soluble sugar through decreasing the production of ethylene followed by reduced respiration rate (Burg and Burg, 1967; Agar and Strief, 1996).

Disinfection treatments were also significant ($P \leq 0.05$) in altering the total sugar contents of mango fruits during the storage period (Table 3). On day 3, hot water at 46°C and hot water at 52°C gave the highest levels of total sugars while mango fruits treated with chlorinated water had the least total sugars contents. On day 7, chlorinated water and on day 14, tap water treated mango fruits had the highest level of total sugar that declined afterwards. On day 21, hot water (52°C) treated mango fruits had the highest level of total sugars. After 28 days of storage, mango fruits treated with hot water (46°C) had the highest level of total sugars. Pervious finding indicated that the hot water treatment for mango fruits does not have a substantial adverse effect on the chemical quality parameters of the fruits (Keryl et al., 2001). In general, disinfection treatments had a positive ($P \leq 0.01$) effect on total sugar content of mangoes; especially, hot water dipping treatments are known to reduce enzyme activities and respiration rate of fruits and vegetables (Lakshminarayana et al., 1974) and hence decrease the rate of determination of sugar.

Interaction effects of disinfecting with packaging and disinfecting with storage environment were significant ($P \leq 0.01$) on the changes in the total sugar content. Similarly, packaging and storage environment had a significant ($P \leq 0.05$) interaction during the storage period (Table 3). The three way interaction between disinfections, packaging and storage environment on the total sugar content of mango fruits was significant throughout the storage period (Table 3). On day 3, hot water (52°C) treated unpackaged mango fruits stored at ambient condition; on day 7, chlorinated water treated and packaged mango fruits stored at evaporative cooler inside air condition; on day 14, tap water treated mango fruits unpackaged and stored at evaporative cooling conditions; on day 21 and 28, hot water at 52°C and chlorinated water and hot water (52°C) treated mango fruits packaged and stored in cooled storage had the highest levels of total sugar. In general, the result showed that the over all total sugar content of mango fruits was maintained better when mango fruits were dipped in chlorinated water and hot water at 52°C, packaged and stored in the evaporative cooling system. Storage condition influenced the effectiveness of post-harvest treatments on the nutritional qualities of mango fruits

Table 3. Effects of postharvest disinfecting, packaging and storage treatments on total sugar content of mangoes over a storage period of 28 days.

Treatments	Total sugar (g 100 g^{-1})				
	3 days	7 days	14 days	21 days	28 days
Packaged, cool storage					
NaOCl	3.16^{h}	9.69^{a}	7.91^{cd}	6.42^{b}	5.51^{a}
H_2O, 52°C	3.46^{g}	9.13^{bcd}	8.84^{b}	6.68^{a}	4.86^{c}
H_2O, 46°C	4.16^{de}	6.78^{j}	7.56^{d}	5.74^{d}	5.42^{a}
H_2O, 23°C	2.56^{i}	8.75^{de}	8.65^{b}	5.53^{ef}	4.43^{d}
Control	3.75^{f}	7.38^{i}	6.49^{ef}	5.37^{fg}	2.62^{f}
Unpackaging, cool storage					
NaOCl	2.23^{j}	9.22^{bc}	7.75^{cd}	5.64^{de}	4.34^{d}
H_2O, 52°C	3.03^{gh}	9.13^{bcd}	8.23^{bc}	6.12^{c}	3.79^{e}
H_2O, 46°C	3.03^{h}	7.80^{ghi}	7.49^{d}	5.34^{g}	5.24^{b}
H_2O, 23°C	3.00^{h}	9.52^{ab}	9.51^{a}	5.76^{d}	4.39^{d}
Control	2.30^{ij}	8.84^{cde}	4.95^{i}	4.64^{h}	2.75^{f}
Packaged, ambient storage					
NaOCl	3.14^{h}	6.49^{i}	5.31^{hi}	-	-
H_2O, 52°C	4.07^{de}	7.52^{hi}	5.63^{gl}	-	-
H_2O, 46°C	4.32^{cd}	7.62^{hi}	6.42^{ef}	-	-
H_2O, 23°C	3.87^{ef}	6.55^{j}	5.37^{hi}	-	-
Control	4.66^{b}	8.98^{cd}	5.45^{ghi}	-	-
Unpackaging, ambient storage					
NaOCl	4.35^{ed}	9.19^{bcd}	7.55^{d}	-	-
H_2O, 52°C	5.39^{a}	7.69^{hi}	6.09^{fg}	-	-
H_2O, 46°C	4.05^{def}	8.15^{fg}	5.71^{gl}	-	-
H_2O, 23°C	4.25^{ed}	7.97^{gh}	6.87^{e}	-	-
Control	4.52^{bc}	8.53^{ef}	6.80^{e}	-	-
C.V	4.7	2.96	5.24	1.71	2.36
S.E	0.10	0.141	0.21	0.06	0.07
Significance					
A	***	**	**	**	***
B	*	**	*	**	**
C	***	***	***	-	-
A x B	***	***	***	*	**
A x C	***	***	***	-	-
B x C	***	*	***	-	-
A x B x C	**	**	*	-	-

Initial (0 day) total sugar was 2.25 g 100 g^{-1} of fresh weight and the data from day 21 onwards are mean values for the evaporatively cooled storage storage.
A, Disinfection; B, packaging; C, storage.
*, **, *** indicate significant difference at P ≤ 0.05, 0.01 or 0.001, respectively.
Means within the same column followed by a common letter are not significantly different at P ≤ 0.05 (DMRT).

during storage, which was demonstrated by the interactive effect of storage conditions with the other post-harvest treatments.

Conclusions

Physiological, chemical and microbiological changes are rapid in mangoes. Post-harvest disinfection, packaging and evaporative cooling systems were combined to bring synergistic effect in shelf life improvement of mangoes. The data changes in reducing, non-reducing and total sugars in mangoes were produced during the 28 days of storage at ambient conditions and cooled storage. There was significant difference among disinfecting treatments in their effect on reducing sugar, non-reducing sugar and total sugar during storage. Sugar content in stored mango fruits was better maintained through the combin-

ing disinfection, packaging with low density Xtend® film and evaporative cooling storage, where relatively lower temperatures and higher relative humidity were maintained compared to the ambient condition. Statistically, significant ($P \leq 0.01$) interactions were found among prepackaging, disinfection and packaging treatments in terms of maintenance of sugars in the mangoes during the storage period. In summary, this result clearly indicated that combining prepackaging disinfection and packaging with evaporatively cooled storage maintained the sugar content during storage.

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