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Influence of temperature on physicochemical changes in mango fruit during storage

Badshah Islam*, **Abdur Rab**

Department of Horticulture, The University of Agriculture, Peshawar, Pakistan

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Abstract

Mango fruits cannot be stored for longer time at ambient temperature due to its highly perishable nature. By contrast low temperature storage may cause chilling injury. Therefore, the storage performance of mango cv. "Langra" fruits at different temperatures was investigated to optimize the temperature for storage of mango fruit. The experiment was laid out in Completely Randomized Design with three repeats. Fruits were stored at 5, 10 and 15 ± 1 ºC for 0, 5, 10, 15, 20, 25 and 30 days and evaluated for fruit firmness (kg cm^{-2}), TSS (°Brix), titratable acidity, reducing sugars and non-reducing sugars after completion of the respective storage period. TSS (°Brix) and reducing sugars increased with the rise in temperature and storage duration. Fruit firmness (kg cm^{-2}), titratable acidity and non-reducing sugars exhibited an inverse relation with storage temperature and duration. The interaction of storage durations and temperatures revealed the highest TSS (18.67 °Brix) and reducing sugars (4.57%) in fruits stored for 30 days at 15 ± 1 ºC. Fruit firmness, titratable acidity and non-reducing sugars were the highest on day 0 however, after 30 days these treatments were higher (10.16 kg cm^{-2}), (1.64%) and (6.92%) respectively, at 5 ± 1 ºC as compared to 10 and 15 ± 1 ºC. It was concluded that if the incidence of chilling injury is overcome, the quality of mango fruit could be maintained for longer time in storage at 5 ± 1 ºC otherwise fruits may be stored at 10 ± 1 ºC.

* **Corresponding Author:** Badshah Islam ✉ badshahislam@gmail.com

Introduction

Mango (*Mangifera indica* L.) is an important member of family Anacardiaceae and is known as the king of fruits. It is native to Indo-Burmese region (Subramanyam *et al.,* 1975) and is widely cultivated in the areas with tropical and subtropical climatic conditions (Tjiptono *et al.,* 1984). Nutritionally, it is an important fruit (Wen *et al.,* 2006). It is a rich source of carbohydrates, vitamins, minerals, proteins and fats (Rao and Mukherjee, 1989; Talcott *et al.,* 2005; Iqbal *et al.,* 2012). Pakistan stands fourth (Maqbool *et al.,* 2007) with a share of 7.8% in the world mango export (Sauco, 2004). Mango fruit is predominantly consumed as fresh but the production season is very short therefore, it is necessary to store it under appropriate conditions to ensure its availability for longer time (Pesis *et al.,* 2000). However, the increasing physiological processes with the extension in storage lead to the reduction in fruit quality (Herianus *et al.,* 2003).

Mango is a climacteric fruit, characterized by high rates of respiration (Wongmetha *et al.,* 2012) and ethylene production (McCollum *et al.,* 1993). Hence, it is a highly perishable fruit (Gil *et al.,* 2000) and susceptible to postharvest losses (Amin *et al.,* 2008). Generally, mature green mango fruits are harvested to extend the postharvest life because it takes 9 to 12 days for ripening process after harvest (Herianus *et al.,* 2003). Due to the highly perishable nature of mango fruits, the postharvest handling technologies have a significant influence on the quality and consumers' acceptance of mango fruits (Rathore, 2007). The high perishable nature of mango fruits also limits its international trade (Gil *et al.,* 2000), especially where long distance transports is through sea.

Various technologies such as controlled atmosphere storage (Bender *et al.,* 2000), modified atmosphere storage (Gonzalez-Aguilar *et al.,* 1997), use of different coatings (Abbasi *et al.,* 2009) and application of different chemicals such as methyl jasmonate (Gonzalez-Aguilar *et al.,* 2000), 1-MCP (Manganaris *et al.,* 2007), methyl salicylate (Junmatong *et al.,* 2012) etc. have been tested to reduce the physiological changes taking place in fruits during storage and thus to delay the onset of senescence (Medlicott and Jeger, 1987). The quality of fruits and vegetables can be maintained by temperature management (Jobling, 2000). Low temperature reduces the metabolic processes and prolongs the postharvest life of fruits and vegetables (Sivakumar *et al.,* 2011). The temperate fruits can easily be stored at low temperature (0-5 °C). However, the tropical and subtropical fruits may undergo chilling injury at similar temperatures (Lizada, 1991; Acosta *et al.,* 2000). Mango being a tropical fruit, is also sensitive to low temperature (below 10 ºC) but the sensitivity varies among different cultivars because some varieties may be stored at temperature as low as 7 ºC while others develop chilling injury at 13 ºC (Mitra and Baldwin, 1997). Lenticel browning, surface discoloration, internal break down, surface pitting and decay are the major symptoms of chilling injury in mango fruit (Kader, 1992: Mitra and Baldwin, 1997).

Keeping in view the importance of low temperature application and its limitations for mango fruit, this experiment was designed to evaluate mango cv. "Langra" fruits under various temperatures and storage durations for quality attributes.

Materials and methods

Materials and experimental design

Mango fruits of cv. "Langra" were harvested at physiological maturity from mango grove at Agricultural Extension Farm, Dera Ismail Khan and transported in corrugated card board boxes on the same day to the laboratory. The fruits were washed thoroughly to remove latex and dried with a gentle blow of air from an electric fan. The fruits were grouped for allocation to storage durations i.e. 0, 5, 10, 15, 20, 25 and 30 days (factor A) at 5, 10 and 15 ± 1 °C (factor B). The experiment was laid out in Completely Randomized Design with three repeats. Ten fruits were included in each treatment per repeat. After completion of the respective storage duration fruits were analyzed for firmness, TSS, titratable acidity, reducing sugars and non-reducing sugars.

Methods of recording data

Fruit firmness was determined by using a penetrometer (model, FT 327 made in Italy) with 8mm plunger. After peeling, two readings were taken at the equatorial region on opposite sides on the flesh of each fruit and the average was calculated for each treatment (Magness and Taylor, 1925). For determination of total soluble solids the standard method of AOAC (2000) was used. The prism of a hand refractometer (model, RHB, 0-80 degree) was thoroughly washed twice with distilled water and dried with tissue paper. A drop of juice prepared from mango fruits of each treatment was placed on it. Three readings for each treatment were taken and then the average was recorded. Titratable acidity of the selected mango juice was determined by standard method of AOAC (2000), by titrating against standard alkali solution and was expressed as citric acid percentage. Mango juice (10 ml) was taken in a beaker, diluted with 100 ml distilled water and two drops of phenolphthalein was added as indicator. Titration was carried out against 0.1 N Sodium hydroxide solution till the appearance of light pink color. The acidity was calculated by the following formula.

$$\text{Acidity}\,(\%) = \frac{T \times Acid\ \ factor \times 100}{L \times M} \times 100$$

T = ml of NaOH used.

L = Sample taken (ml) for dilution

M = ml of diluted sample taken for titration

Reducing sugars were determined according to AOAC (2000) procedure. Mango juice (10 g) was dissolved in 100 ml distilled water and the burette was filled with it. 5 ml Fehling A and 5 ml Fehling B solution along with 10 ml distilled water was taken in a conical flask. The flask was heated till boiling. The juice was added from the burette till the appearance of red brick color. A drop of methylene blue was used to check the persistency of red brick color. The titration continued till complete reduction of sugars. As 5 ml of Fehling A and 5 ml of Fehling B will reduce 0.05 g of reducing sugars so the calculations was carried out as under.

$$\text{Reducing sugars}\,(\%) = \frac{0.05 \times dilution \times 100}{Weight\ of\ sample \times titre}$$

For the determination of non-reducing sugars, a sample of 10 g was dissolved in 100 ml of distilled water. 20 ml of this solution was taken in flask and 10 ml of 1N HCL was added to it. The flask was heated for 5-10 minutes and then 10 ml of 1N NaOH was added. The volume was made to 250 ml. This solution was taken in a burette and titrated against the boiling solution of 5 ml Fehling A and 5 ml Fehling B solution taken in a flask with 10 ml distilled water. The titration continued till the appearance of red color of which persistence was checked with a drop of methylene blue. In this way, total sugars were calculated. Non-reducing sugars were calculated as:

Non-reducing sugars = Total sugars – Reducing sugars

Statistical analysis

The data collected was subjected to Analysis of Variance (ANOVA) using statistix 8.1 software (Analytical Software, 2003). Upon significant differences, the LSD (least significant difference) test was applied for separation of means (Steel and Torrie, 1980).

Results and discussion

Fruit firmness (kg cm^{-2})

Storage durations, temperatures, and their interaction significantly affected the fruit firmness. The results revealed that mean firmness declined with the increase in storage duration. The maximum fruit firmness (12.77 kg cm^{-2}) was recorded at 0 day storage, followed by 10.14 kg cm^{-2} in fruits stored for 5 days while the lowest fruit firmness (4.65 kg cm^{-2}) was after 30 days storage. The firmness also decreased with the increase in temperature which was the highest (11.49 kg cm^{-2}) in fruits stored at 5 ± 1 ^{o}C followed by 6.97 kg cm^{-2} of 10 ± 1 ^{o}C whereas, the least firmness (5.15 kg cm^{-2}) was measured at 15 ± 1 ^{o}C. The interaction of storage durations and temperatures depicted that the fruit firmness decreased with the increase in both, storage temperature and duration (Figure 1.1) with the maximum decrease in firmness recorded in fruits stored at 15 ± 1 °C which decreased from 12.77 kg cm^{-2} at 0 day to 1.62 kg cm^{-2} with 30 days storage.

Structural carbohydrates such as starch and pectic substances are responsible for maintaining firmness of fruits (Manganaris *et al*., 2008). The decrease in firmness with the increase in storage duration is due to the increasing ripening processes, conversion of protopectin to soluble pectin through increased pectin esterase (Abd-El- Magid, 1986) and moisture loss (Ezz and Awad, 2011; Hafeez *et al.*, 2012). Generally, the rate of metabolism such as respiration (Gorny, 1998; Ahmad, 2001; Ezz and Awad, 2011) and hydrolysis of starch (Thompson, 1996) are higher at higher temperatures.

Table 1. Influence of storage temperatures and durations on mean fruit firmness (kg cm^{-2}), TSS (°Brix), titratable acidity (%) Reducing sugars (%) and Non-reducing sugars (%) during storage.

Treatments	Fruit firmness (kg cm^{-2})	TSS (°Brix)	Titratable acidity (%)	Reducing sugars (%)	Non-reducing sugars (%)
Temperature (T, °C)					
5	11.49 a	11.57 c	1.86 a	3.36 c	8.01 a
10	6.97 b	16.67 b	1.30 b	3.55 b	7.23 b
15	5.15 c	17.97 a	0.97 c	3.78 a	6.72 c
LSD at α = 0.05	0.36	0.23	0.03	0.05	0.10
Storage duration (SD, days)					
0	12.77 a	9.98 f	2.06 a	2.81 g	8.81 a
5	10.14 b	13.28 e	1.74 b	3.12 f	8.13 b
10	8.36 c	15.22 d	1.52 c	3.35 e	7.64 c
15	7.51d	16.61 c	1.35 d	3.52 d	7.27 d
20	6.24 e	17.67 a	1.18 e	3.89 c	6.78 e
25	5.43 f	17.94 a	0.97 f	4.06 b	6.43 f
30	4.65 g	17.11 b	0.83 g	4.19 a	6.17 g
LSD at α = 0.05	0.54	0.34	0.04	0.07	0.14
Interaction					
T x SD	**	**	**	**	**

** = Significant at p≤0.01

In each category, means followed by different letter (s) are significantly different from each other at 5% level of probability using LSD test.

The activities of cell wall degrading enzymes such as Pectinesterase, Polygalacturonase, and Pectateliase (Rasmussen *et al.,* 1992, Thompson ,1996 and Manganaris *et al.,* 2007) are also higher at high temperature. Collectively all such activities may resulted in rapid degradation of cell wall (pectin substances) and decreased the fruit firmness. It is therefore, likely to observe higher firmness in fruits stored at 5 ± 1 °C as compared to 10 and 15 ± 1 °C. Gonzalez-Aguilar (2000) reported similar decrease in fruit firmness of mango with the increasing storage. Thus, it is clear that increasing storage duration and temperature result in loss of fruit firmness and the least firmness was observed after 30 days storage at 15 ± 1 °C.

Total soluble solids (°Brix)

The influence of storage durations, temperatures and their interaction on TSS was significant. The TSS was maximum (17.94 °Brix) with 25 days storage followed by 17.67 °Brix after 20 days whereas, the minimum TSS (9.98 °Brix) was recorded on day 0 of storage. The total soluble solids increased with the increase in storage temperature with the highest total soluble solids (17.97 °Brix) recorded in fruits stored at 15 ± 1 °C followed by 16.67 °Brix at 10 ± 1 °C whereas, 5 ± 1 °C resulted in the least total soluble solids (11.57 °Brix). The interaction of storage duration and temperature revealed that TSS increased to day 20 of storage at 15 ± 1 °C and then declined whereas, the same trend was found after 25 day in fruits stored at 10 ± 1 °C. The lowest increase in TSS was observed at 5 ± 1 °C with the storage however, this increase continued till 30 day. The maximum TSS (21.33 °Brix) was recorded in fruits stored for 25 days at 10 ± 1 °C (Fig. 1.2).

The total soluble solids represent the soluble metabolites including sugars and organic acids of the fruit (Salisbury and Ross, 1985). As the storage time progressed, the TSS increased with a slight decrease on day 30, which is because of reduction at 15 ± 1 °C. Although the organic acid content that contributes to the TSS decreased but total soluble solids increased possibly due to the conversion of structural sugars into simpler form with the increasing storage duration (Rathore *et al.,* 2007; Ezz and Awad, 2011; Sajid *et al.,* 2012).

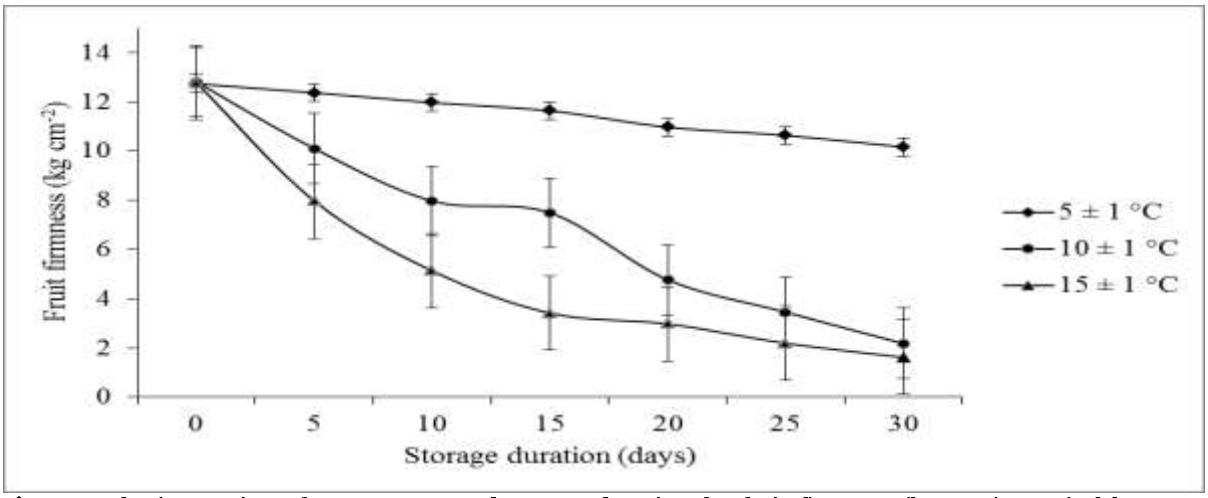

Fig. 1.1. The interaction of temperature and storage duration for fruit firmness (kg cm^{-2}). Vertical bars are standard errors of means.

The increase in TSS with increasing storage duration has also been reported by Rab *et al.* (2011), while evaluating the biochemical changes in citrus. At higher temperature, the conversion of complex carbohydrates into simpler sugars is accelerated (Ahmad *et al.,* 2001) that increased total soluble solids. Whereas, at low temperature ripening is delayed and the hydrolysis of starch is slow (Medlicott *et al.,* 1986; Ezz and Awad, 2011). Thus, fruits stored at 5 ± 1 °C had the least total soluble solids. The interaction of temperature and storage duration revealed a consistent increase in TSS with storage at 5 ± 1 °C whereas, at higher temperatures the TSS decreased that may be due to the accelerated respiration resulting in a decline of organic acids and total sugars.

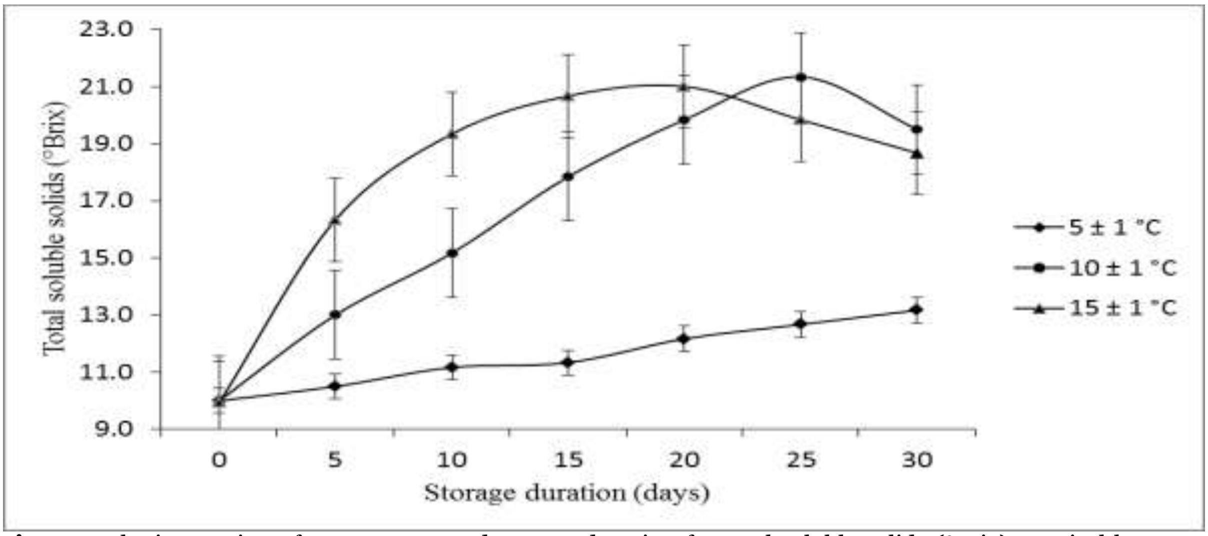

Fig. 1.2. The interaction of temperature and storage duration for total soluble solids (°Brix). Vertical bars are standard errors of means.

Titratable acidity (%)

The storage durations, temperatures, and their interaction significantly affected the titratable acidity. The titratable acidity declined with the increasing storage duration. The maximum (2.06%) titratable acidity was on day "0" which decreased to the minimum (0.83%) in fruits stored for 30 days. Similarly, the titratable acidity declined with the increasing temperature. The fruits stored at 5 ± 1 ºC maintained the highest titratable acidity (1.86%) followed by 10 ± 1 ºC (1.30%) whereas, the lowest results (0.97%) were obtained for 15 ± 1 ºC. The interaction of storage durations and temperatures was also significant and revealed that while the acidity decreased with the increase in both storage temperature and duration. However, the decrease in acidity with the increasing storage duration at 5 ± 1 ºC was slow as compared to that of 10 and 15 ± 1 ºC (Fig. 1.3).

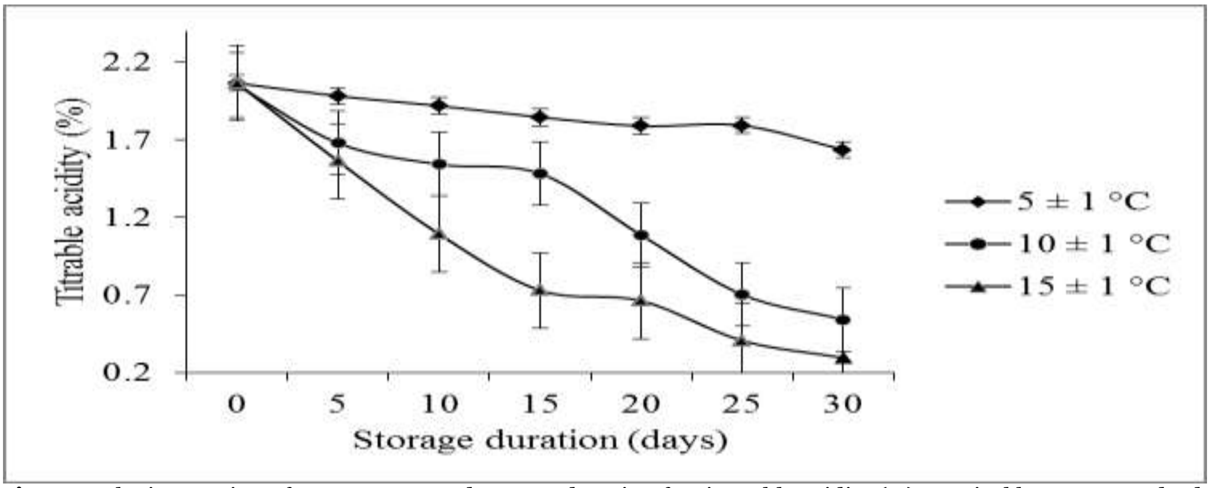

Fig. 1.3. The interaction of temperature and storage duration for titratable acidity (%). Vertical bars are standard errors of means.

Acidity is an important characteristic for fruits quality (Abbassi *et al.,* 2009). The titratable acidity gradually declined with the increase in storage duration that is due to the consumption of organic acids in respiratory metabolism (Pesis *et al.,* 1999; Abbassi *et al.,* 2009; Rab *et al.,* 2011). Similarly, the organic acids are depleted rapidly at higher temperature due to accelerated respiration (Seyoum, 2002; Wen *et al.,* 2006; Ezz and Awad, 2011). Thus, titratable acidity was the least at 15 ± 1 ºC. Since the overall metabolism is slower at lower temperature (5 ± 1 ºC) higher organic acid content was retained leading to higher acidity.

Reducing sugars (%)

The mean data depicted that storage durations, temperatures and their interaction significantly influenced the reducing sugars. Within the stipulated storage period, the reducing sugars were found to be directly proportional to storage duration. Reducing sugars were maximum (4.19%) in fruits stored for 30 days while minimum (2.81%) on day 0. The reducing sugars increased with the increasing storage temperature. The highest reducing sugars (3.78%) were measured in fruits stored at 15 ± 1 ºC followed by 3.55% sugars at 10 ± 1 ºC whereas, the least results (3.36%) were obtained at 5 ± 1 ºC. The interaction of storage durations and temperatures (Figure 1.4) revealed that reducing sugars content increased with the increase in both storage temperature and duration and the increase was lower at 5 ± 1 ºC than 15 ± 1 ºC. Thus, the highest reducing sugars were recorded in fruits stored at 15 ± 1 ºC for 30 days.

The major reducing sugars include glucose and fructose. The increased reducing sugars with the extended storage might be due to the breakdown of starch or increase moisture loss resulting in increased concentration of non-reducing sugars (Rab, *et al.,* 2011). The greater increase in reducing sugars at high temperature can be attributed to the accelerated activities of enzymes (Yoshida *et al.,* 1984) responsible for converting starch (Ahmad *et al.,* 2001) and sucrose into glucose and fructose (Hassan *et al.,* 2004). The slow increase in reducing sugars is due to delayed ripening (Youssef *et al.,* 2002) at 5 ± 1 °C. The relatively low increase in the reducing sugars content with storage at 5 ± 1 °C as compared to higher temperatures can be attributed to the reduced metabolic processes and slow conversion of non-reducing sugars (Wen, 2006; Ezz and Awad, 2011).

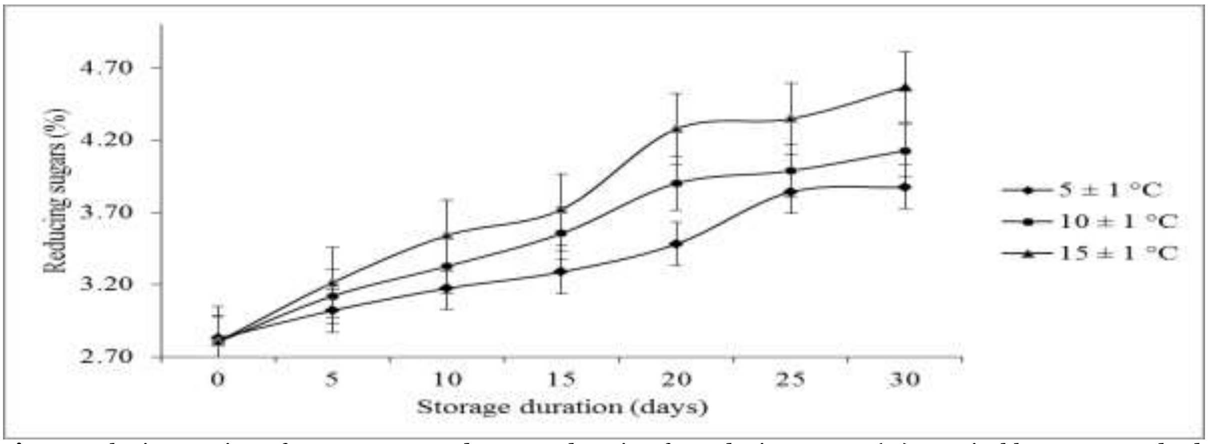

Fig. 1.4. The interaction of temperature and storage duration for reducing sugars (%). Vertical bars are standard errors of means.

Non-reducing sugars

A significant influence of storage durations, storage temperatures and their interaction was observed on non-reducing sugars. Non-reducing sugars decreased with the increase in storage duration. The highest content of non-reducing sugars (8.81%) was measured on 0 days storage followed by 8.13% in fruits stored for 5 days whereas, the least non-reducing sugars (6.17%) were recorded with 30 days storage. The non-reducing sugars also showed an inverse relation with the storage temperature. The maximum non-reducing sugars (8.01%) were recorded in fruits stored at 5 ± 1 °C while the minimum (6.72%) at 15 ± 1 °C. The interaction of storage durations and temperatures showed an inverse relation with both storage temperature and duration in the non-reducing sugars content of mango fruit. The greatest decrease was observed in fruits stored at 15 ± 1 °C. By contrast, storage temperature of 5 ± 1 °C resulted in a slow decline in non-reducing sugars with increasing storage duration (Fig. 1.5).

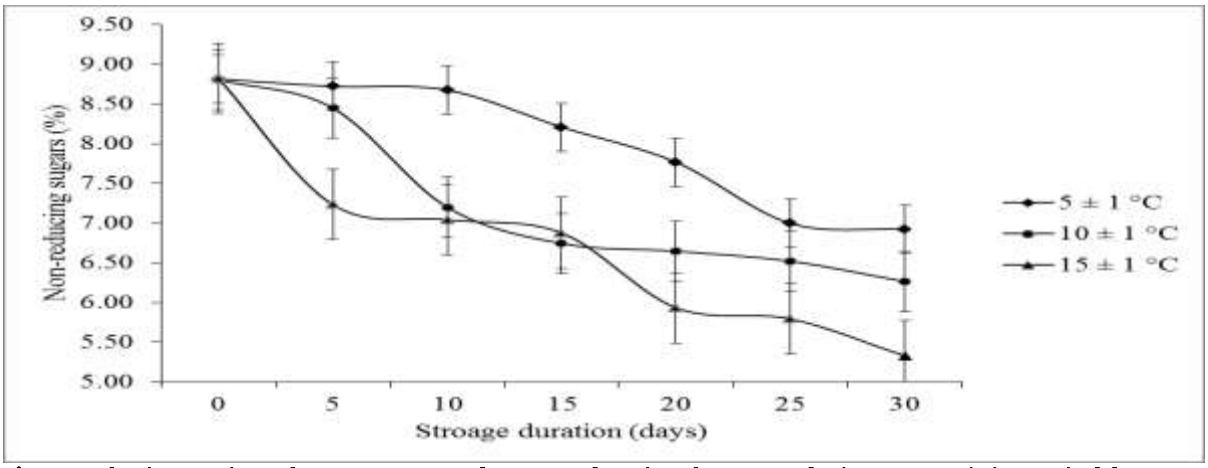

Fig. 1.5. The interaction of temperature and storage duration for non-reducing sugars (%). Vertical bars are standard errors of means.

The decline in non-reducing sugars with the increasing storage duration can be due to the breakdown and hydrolysis of non-reducing to reducing sugars (Hafeez *et al.,* 2012; Sajid *et al* 2012; Tadessee *et al.,* 2012). The non-reducing sugars decrease after harvest and rate of decline depends on storage temperature (Arjona *et al.,* 1992).

The metabolic processes are generally higher at higher temperature. High temperature triggers the conversion of oligosaccharides and polysaccharides to reducing sugars i.e. glucose and fructose, utilized as substrate in respiration (Ahmad *et al.,* 2001). Thus, high temperature rapidly declined the non-reducing sugars content. Similarly, the retention of the highest non-reducing sugars at low temperature might be due to slow rate of these processes (Arjona *et al.,* 1992) at 5 ± 1 °C. The rapid decrease in non-reducing sugars with increasing storage at 15 ± 1 °C may be due to accelerated enzymatic activities and ripening (Medlicott *et al.,* 1990).

Conclusion

TSS and reducing sugars increased whereas, fruit firmness, titratable acidity and non-reducing sugars decreased with the increase in storage duration. Fruits stored at 5 ± 1°C retained the highest firmness, titratable acidity and non-reducing sugars that were followed by 10 ± 1°C and all these attributes decreased with increasing storage duration. Storage of mango cv. “Langra” fruits at 5 ± 1 °C showed better results for quality attributes but suffered chilling injury (data not shown). On the other hand, storage at 15 ± 1 °C resulted in rapid loss of quality. Quality loss and chilling injury was the modest at 10 ± 1 °C therefore, if proper measures are not available for alleviation of chilling injury then fruits may be stored at 10 ± 1 °C.

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