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# Influence of Hot Water Treatment and Storage Period on Physico-chemical Properties of Williams Hybrid *(Giant cavendish)* Banana Fruit

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**Abstract.** Banana, a perishable agricultural product due to its poor handling and processing practices results in severe postharvest losses. The experiment evaluating the impact of hot water on the quality characteristics of banana was carried out at the Department of Farm Structures and Postharvest Engineering. The banana samples were subjected to different treatments i.e. immersed in unheated water (TRc) and at three different temperatures i.e. 40 ($TR_{40}$), 50 ($TR_{50}$) and 60°C ($TR_{60}$). The samples after treatment were stored for a duration of fifteen days. The results revealed that the quality of banana was significantly affected by the treatments being applied (P≤0.05). It was observed that treatment $TR_{50}$ retained average maximum values for moisture content (%), fruit pulp firmness (N), pulp to peel ratio, titratable acidity (%) and ash content (%) and average minimum values for peel colour, pulp pH, total sugar content (%), decay incidence (%) and weight loss (%) followed by $TR_{40}$, TRc and $TR_{60}$. The results for parameters increased with increasing days of storage except for moisture content, firmness, titratable acidity and ash content. The study concluded that the quality and shelf life of banana sample was better maintained when treated at a temperature of 50 °C ($TR_{50}$). The current study strongly suggests the adoption of hot water treatment at farm level to reduce the postharvest losses of banana fruit.

**Keywords**: williams hybrid, banana, hot water, storage, physical, chemical properties

## Introduction

Banana in many countries is cultivated as an ripen fruit, cooked vegetables and leaves (Khanum *et al*., 2000) and is ranked as eight important in the world (Ploetz, 2015). It is considered to be a good source of income for the farmers of respective growing regions (Atkins *et al*., 2020). Nutritiously it is high and can easily be digested than many other fruits (Keerio *et al*., 2018). While accounting the supplies and global exports excluding plantain, it has attained a record of 19.2 million tons in 2018, which as compared to 2017 had a growth of 4.4% (FAO, 2018). In post-harvest sector the loss of fresh produce has always remained a major challenge, out of which fruits are most perishable produces facing high losses, while comparing with others (Bhattarai and Gautamm, 2006). For edible fruits, ripening process is considered to be an important economic aspect (Liang *et al*., 2020). Banana, a climacteric fruit possess poor storage characteristics due to its rapid respiratory rate and ethylene production after harvesting (Turner, 1997). The study of Chen *et al*. (2019) reported that rapid senescence after ripening reduces the storage time of harvested banana. It has been reported that the banana peel's physical, chemical and antioxidant properties at different ripening stages occurs significant changes (Vu *et al*., 2019). The Ziegler *et al*. (2020) reported that storage period and temperature significantly affects the fresh produce. Quality of banana deteriorates rapidly as fully ripened, this reduces its shelf life, limiting the marketing of the fruit. (Ummarat *et al*., 2011). These limiting factor therefore makes export of bananas to distant countries, mainly due to development of postharvest diseases (Win *et al*., 2007). The anthracnose and crown rot disease are considered to be the major post-harvest diseases (Ali *et al*., 2018). Extending the shelf life of bananas may be of great commercial benefit to both exporters and retailers (Dissanayake *et al*., 2015). Chukwu *et al*. (2011) for their study reported that storage method and storage

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period both effected the quality characteristics of banana where Khanbarad *et al*. (2012) for their study reported an increase in weight loss, total soluble solids, total sugar and pulp to peel ratio and an decrease in acidity and firmness with increasing days of storage, while Ahmad and Thompson (2006) studying the effects of controlled atmosphere storage reported a significant change in quality with increasing storage days.

As demonstrated by many researches being carried out on fruit crops, post-harvest diseases could also be suppressed by postharvest treatments (Soomro *et al*., 2020; Promyou *et al*., 2008). In order to extend the shelf life of bananas, different treatments i.e. fungicides, chemical and low temperature are being adopted where post-harvest heat treatment can be a pesticide-free method for reducing plant pathogens, controlling insect infestations and maintaining the quality of fruit storage (Zhang *et al*., 2010). There has been an increasing trend over the last few years towards the use of post-harvest heat treatments, which is reported to be a safe process including i.e. hot water and hot air treatments. It is successfully being used to control the postharvest losses in several commodities (Khan *et al*., 2019). This treatment inhibits the ripening process, softening of fruit and increases its shelf life (Varit and Songsin, 2011). Hot water is an efficient medium for heat transfer, which establishes a uniform temperature profile (Couey, 1989). Banana treated with hot water was found to be beneficial to consumer/trader, when its shelf increased by 30%, reducing its post-harvest losses by 70% when compared to untreated fruits (Amin and Hossain, 2013). Indeed, the overall quality of fresh products treated at the optimum temperature of hot water was significantly better than untreated products, as determined by a significant decrease in the decay incidence and the maintenance of several quality characteristics (Amin and Hossain, 2012). This study observing the losses of quality characteristics of banana was designed to assess the effects of hot water treatment and storage period on physico-chemical properties of Williams hybrid *(Giant cavendish)* banana fruit.

## Materials and Methods

The study observing the effects of hot water treatment and storage period on banana fruit was carried out at the Department of Farm Structures and Postharvest Engineering, Sindh Agriculture University, Tandojam. Green matured Williams hybrid (*Giant cavendish*) banana variety (Fig. 1a) was used for experimentation. Banana sample prior to experiment were first washed with distilled water for removing soil particles and other foreign materials. The samples after washing were subjected to different hot water treatments (Table 1), packed in 4 µm polyethylene bags and then stored for fifteen days under ambient conditions for observation. The quality in terms of physico-chemical properties and its shelf life was observed initially and then at an interval of five days.

**Moisture content (%).** Oven drying method was used for determining the moisture content of banana pulp. The samples were weighed and kept in oven for 24 h at a temperature of 105 °C. The moisture content was measured using following equation (Soomro *et al*., 2019).

$$\text{Moisture content (\%)} = \frac{\text{Wf}-\text{Wd}}{\text{Wf}} \times 100 \quad \text{..................(1)}$$

**Peel colour.** The peel colour of sample fruits were determined using banana maturity stage chart as shown in Fig. 1b (Zewter *et al*., 2012). The ripeness stages are described as 1=green; 2=light green (breaking toward yellow); 3=yellowish-green; 4=greenish-yellow (more yellow then green); 5=yellow with green tips; 6=yellow and 7=yellow flecked with brown.

**Fruit pulp firmness (N).** Firmness is defined as the maximum force required for tissue failure (Soltani *et al*., 2011). Hand penetrometer (Model CL 700 A) was used for determining the firmness of samples. Samples taken as per treatment were dissected horizontally, after which the plunger of penetrometer was then vertically placed into the pulp and pressed, noting its reading (Chancharoenrit, 2002).

**Pulp to peel ratio.** The pulp and peel of banana were weighed separately using digital weight balance. The pulp to peel ratio (Ppr) was determined using following equation (Tapre and Jain, 2012).

$$\text{Pulp to peel ratio} = \frac{\text{Pulp weight (g)}}{\text{Peel weight (g)}} \quad \text{......................(2)}$$

**Table 1.** Hot water treatments

| Treatment | Symbol |
|---|---|
| Untreated water | TRc |
| Treated with 40 °C hot water | $TR_{40}$ |
| Treated with 50 °C hot water | $TR_{50}$ |
| Treated with 60 °C hot water | $TR_{60}$ |

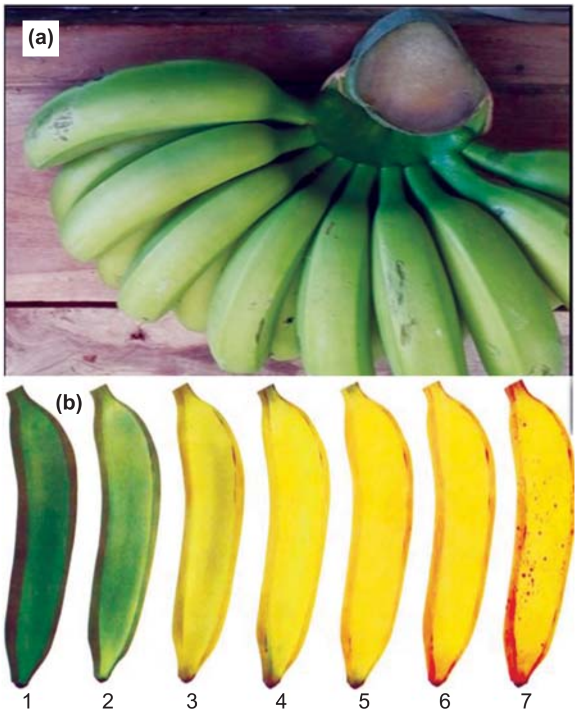


**Fig. 1.** Williams hybrid (*Giant cavendish*) fruit variety **(a)** and banana ripening stages **(b)**.

**Total soluble solids (% brix).** Refractometer (Atago, Japan) was used for determining the total soluble solids (TSS) of fruit pulp and the reading was expressed in percentage (brix). Distilled water was used to standardize the refractometer, adjusting it to 0% brix. For readings, two drops of filtrate were poured on the glass prism of refractometer. TSS was calculated using following formula (AOAC, 1984).

TSS (%) = (refractometer reading × dilution factor) + 0.28

**Titratable acidity (%).** The method as described by AOAC (2005) was used to determine titratable acidity of Banana fruit. Pulp concentration was titrated to 0.1 sodium hydroxide solution using phenolphthalein as indicator, until the colour changed to pink.

**Pulp pH.** pH of pulp was determined by dipping a digital pH meter in concentration (pulp juice) of sample weighing 10 g, blended separately into 40 mL distilled water. The readings were noted for all treatments, replicated thrice (Ranganna, 1986).

**Total sugar content (%).** Lane and Eynon method (SMRI, 1997) was used for determining the total sugar content. Five gram of sample was added to warm water of 100 mL, preparing its solution. Ten mL diluted HCl was added to the prepared 100 mL solution and was then boiled for 05 min. Solution when cooled was neutralized to phenolphthalein with 10% NaOH. The prepared solution was used for titration against Fehling's solution.

Total sugar content (%) = Factor (4.95) × dilution (250) × 2.5

**Ash content (%).** The Ash content is a percentage of total amount of minerals present within a food. Ten g of banana samples were weighed and kept in muffle furnace. The samples were heated for about three hours at a temperature of 600 °C. Following formula was used to determine ash content (AOAC, 1984).

$$\text{Ash (\%)} = \frac{\text{Weight of residue (g)}}{\text{Weight of sample taken (g)}} \times 100 \quad ..........(3)$$

**Decay incidence (%).** The signs of decay was determined visually. The percentage of the decayed fruit was expressed using the following relation (Soomro *et al*., 2016).

$$\text{Decay incidence (\%)} = \frac{\text{Number of infected fruits}}{\text{Total number of fruits}} \times 100 \quad ..........(4)$$

**Weight loss (%).** Samples of banana from each treatment were weighed initially and at an interval of five days. Sensitive weight balance (DT 2K model Lark ® 511214) was used for weighing the balance before and after days of storage. Following equation was used for calculating the weight loss (Soomro *et al*., 2016).

$$\text{Weight loss (\%)} = \frac{\text{Initial weight (g)-Weight (g) at sampling date}}{\text{Initial weight (g)}} \times 100 \quad ..........(5)$$

**Statistical analysis.** Analysis of variance was performed using Statistix software (Ver. 8.1), and the data was analyzed at a significant level of $P \leq 0.05$. OriginPro 2016 was used for graphical representation.

## Results and Discussion

The results obtained from present study revealed that moisture content (%), peel color, fruit pulp firmness

(N), pulp to peel ratio, total soluble solids (% Brix), titratable acidity (%), pulp pH, total sugar content (%), ash content (%), decay incidence (%) and weight loss (%) were observed to be significantly different ($P<0.05$) when treated with different treatments at different storage period (Table 2).

**Moisture content.** The effects of hot water treatments on moisture content of banana fruit is illustrated in Fig. 2a. A reduction in moisture content was observed with increasing storage duration. Moisture content as affected by treatment ranged from 65.48% to 75.01%. The highest average moisture content with 70.22% was observed for treatment $TR_{50}$ (50 ±2 °C), followed by $TR_{40}$ (69.85%) and TRc (untreated hot water treatment) with 69.59% and $TR_{60}$ (69.27%) respectively. The average initial moisture content was observed to be 74.17%, which then decrease to 70.34, 68.23 and 66.19%, when recorded at 5, 10 and 15 days after storage respectively. Decrease in moisture content was due to breakdown of carbohydrates and osmotic transfer from peel into pulp (Khawas and Deka, 2016). Similar decreasing trend of moisture content with increasing respiration rate in fruit has also been reported by Patil and Shanmugasundaram (2015).

**Peel colour.** The peel colour of banana fruit as affected by different treatments is graphically represented in Fig. 2b. The peel colour of Williams hybrid (*Giant cavendish*) banana fruit ranged between 1 to 6 index numbers. Maximum peel colour with 6 was observed for treatments TRc and $TR_{40}$ at 15 days after storage, while with one it was initially observed for all treatments. The variations in fruits peel colour were noticed with an increasing pattern that might be due to degradation of carotenoids pigments that leads to changing of peel colours from dark green to yellow (stage 1 to stage 7) with respect to extended period of storage (Varit and Songsin, 2011; Fallik, 2004).

**Fruit pulp firmness (N).** This is an important parameter, while evaluating the susceptibility to physical or mechanical damage and during the post-harvest handling (Anyasi *et al*., 2015). Fig. 2c demonstrates the influence of treatments on the fruit pulp firmness. It was observed that the firmness decreased with increasing number of storage days and had significantly ($P\leq0.05$) been affected by the treatments being applied (Table 2). Firmness of banana fruit ranged between 2.16 to 7.62 N. The highest average fruit pulp firmness with 5.50 N was recorded for treatment $TR_{50}$, followed by $TR_{40}$ and TRc, while the lowest with 4.92 N was observed for treatment $TR_{60}$. A breakdown may occur of the cell walls with the advancement in ripening process and a decrease in the cohesion of middle lamella might be due to the solubilization of pectic substances (Zewter *et al*., 2012). The firmness of banana was significantly observed to be higher for samples which were treated with hot water reported by Kaur and Kaur (2017). The result are also in line with findings reported by Kulkarni *et al*. (2011) for 'Robusta' banana variety.

**Pulp to peel ratio.** As shown in Fig. 2d, the pulp to peel ratio increased with increasing number of storage days. The influence of treatment was observed to be statistically ($P\leq0.05$) different. Pulp to peel ratio for Williams hybrid *(Giant cavendish)* ranged between 1.80 to 3.16. Highest average values with 2.35 was recorded for treatment $TR_{50}$, while minimum with 2.11 was observed for $TR_{60}$. The carbohydrate breakdown and peel to pulp's osmotic transfer might be the reason for the increase in pulp moisture (Fallik, 2004). Similar results has also been reported by Kaur and Kaur (2017) for banana cv. Grand naine

**Total soluble solids (% brix).** Results for total soluble solids are graphically represented in Fig. 3a and statistically presented in Table 2. A linear increasing trend with increasing storage period was observed when subjected to different hot water treatments which were also statistically different from each other. The value for total soluble solids ranged between 11.22 to 20.69%. The highest total soluble solid (15.52%) was recorded for treatment $TR_{60}$, followed by TRc, $TR_{40}$ and $TR_{50}$. The breakdown of starch into soluble sugars caused the

**Table 2.** Analysis of variance of banana as affected by hot water treatment and storage period

| Source | Sum of squares | Mean squares | F value | $R^2$ |
|---|---|---|---|---|
| Moisture content | 139.57527 | 46.52509 | 81.77959** | 0.953 |
| Peel colour | 40.25 | 13.41667 | 21.46667** | 0.843 |
| Firmness | 62.55843 | 20.85281 | 279.91912** | 0.986 |
| Pulp-peel ratio | 2.97013 | 0.99004 | 64.97402** | 0.942 |
| Total soluble solids | 94.12097 | 31.37366 | 25.4421** | 0.864 |
| Titratable acidity | 0.46032 | 0.15344 | 26.59841** | 0.869 |
| Pulp pH | 4.18805 | 1.39602 | 28.31438** | 0.876 |
| Total sugar content | 245.56873 | 81.85624 | 162.6431** | 0.976 |
| Ash content | 13.24507 | 4.41502 | 24.92632** | 0.862 |
| Decay incidence | 1077.35572 | 359.11857 | 23.21641** | 0.853 |
| Weight loss | 491.84548 | 163.94849 | 209.90109** | 0.981 |

**Note:** **represents significant at $P\leq0.05$

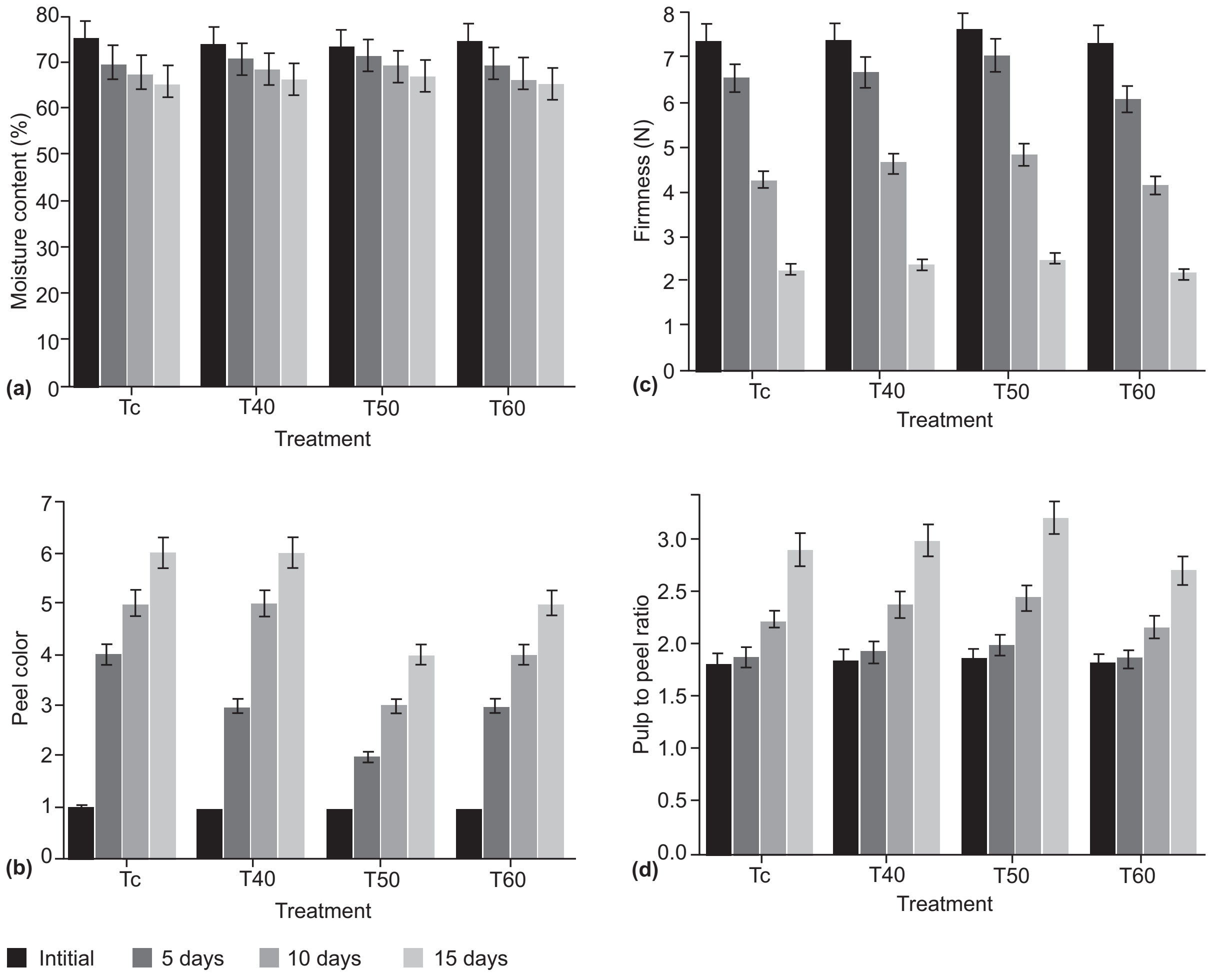


**Fig. 2.** **(a)** Effect of hot water treatments on moisture content, **(b)** peel colour, **(c)** firmness and **(d)** pulp to peel ratio.

increase in total soluble solids (Kulkarni *et al*., 2011). Similar results has also been reported by Maduwanthi and Marapana (2019), Lu (2004) and Nair and Singh (2003).

**Titratable acidity (%).** Results for titratable acidity when observed were statistically ($P \leq 0.05$) different and are illustrated in Fig. 3b. Titratable acidity of banana fruit ranged from 0.21 to 0.80%. The results for highest average titratable acidity with 0.60% was observed for $TR_{50}$, followed by $TR_{40}$ and TRc, while minimum with 0.48% was observed for $TR_{60}$. A linear decreasing trend was observed for titratable acidity with increasing storage period. An increase in total soluble solids resulted the decrease in titratable acidity (Subbaiah *et al*., 2013; Seymour *et al*., 1993). The results are in line with the findings of (Ummarat *et al*., 2011; Hernandez *et al*., 2006).

**Pulp pH.** Results for pulp pH are graphically represented in Fig. 3c. An increase, with increasing storage period was observed for pulp pH. The pulp pH of banana fruit varied from 4.55 to 6.33. Highest average pulp pH with 5.56 was observed for $TR_{60}$, while minimum was observed for $TR_{50}$ (5.17). Increase in pulp pH might be related with increasing titratable acidity. Increasing trend was due to solubilization of peptic substances in cell wall and middle lamella (Dadzie and Orchard, 1997) and have a significant effect on the stability of anthocyanin and colour expression (Holcroft and Kader, 1999).

**Total sugar content (%).** Figure 3d shows the influence on total sugar content for Williams Hybrid *(Giant cavendish)* banana fruit. The total sugar content linear increased with increasing storage period where the effect at fifteenth day was significantly noted to be higher than those of the observations noted initially and at an interval of five and ten days. The values for total sugar content ranged from 4.20 to 14.53%. The average values were higher for $TR_{60}$, followed by TRc, $TR_{40}$ and $TR_{50}$. The increasing trend of total sugar content was the result of rapid induction of climacteric phases in respiratory metabolic pathways in starch hydrolysis (Morrelli and Kader, 2002). Similar results has also been reported by (Salvador *et al*., 2007; Heinemann *et al*., 2005).

**Ash content (%).** Figure 4a illustrates the effect of treatments on ash content of Williams hybrid *(Giant cavendish)* banana fruit, which was observed to be statistically different having an $R^2$ value of 0.862 (Table 2). It was observed that ash content of banana fruit decreased with increasing days of storage. The values ranged between 2.96 to 6.40, where the average value with 4.42% was observed to be maximum when treated with $TR_{50}$. Similar decrease has also been affirmed by the findings reported by (Tapre and Jain, 2012; Varit and Songsin, 2011).

**Decay incidence (%).** Effect of treatments and storage period of decay incidence is shown in Fig. 4b and statistically presented in Table 2. The decay incidence for all treatments was initially 0%, which by increasing days of storage increased. The values for decay incidence ranged between 7.40 to 27.14. The lowest averages value with 7.75% was observed for $TR_{50}$, followed by 13.26, 14.21 and 14.97 for $TR_{40}$, TRc and $TR_{60}$ accordingly. Based on combination of appropriate temperatures (usually above 40 °C) and exposure times to avoid product quality loss, the hot water treatment is a non-conventional approach to decline post-harvest losses (Usall *et al*., 2016). The results obtained are affirmed with the out comings of (Tadesse, 2014; Kitinoja *et al*., 2011; Paull and Chen, 2000).

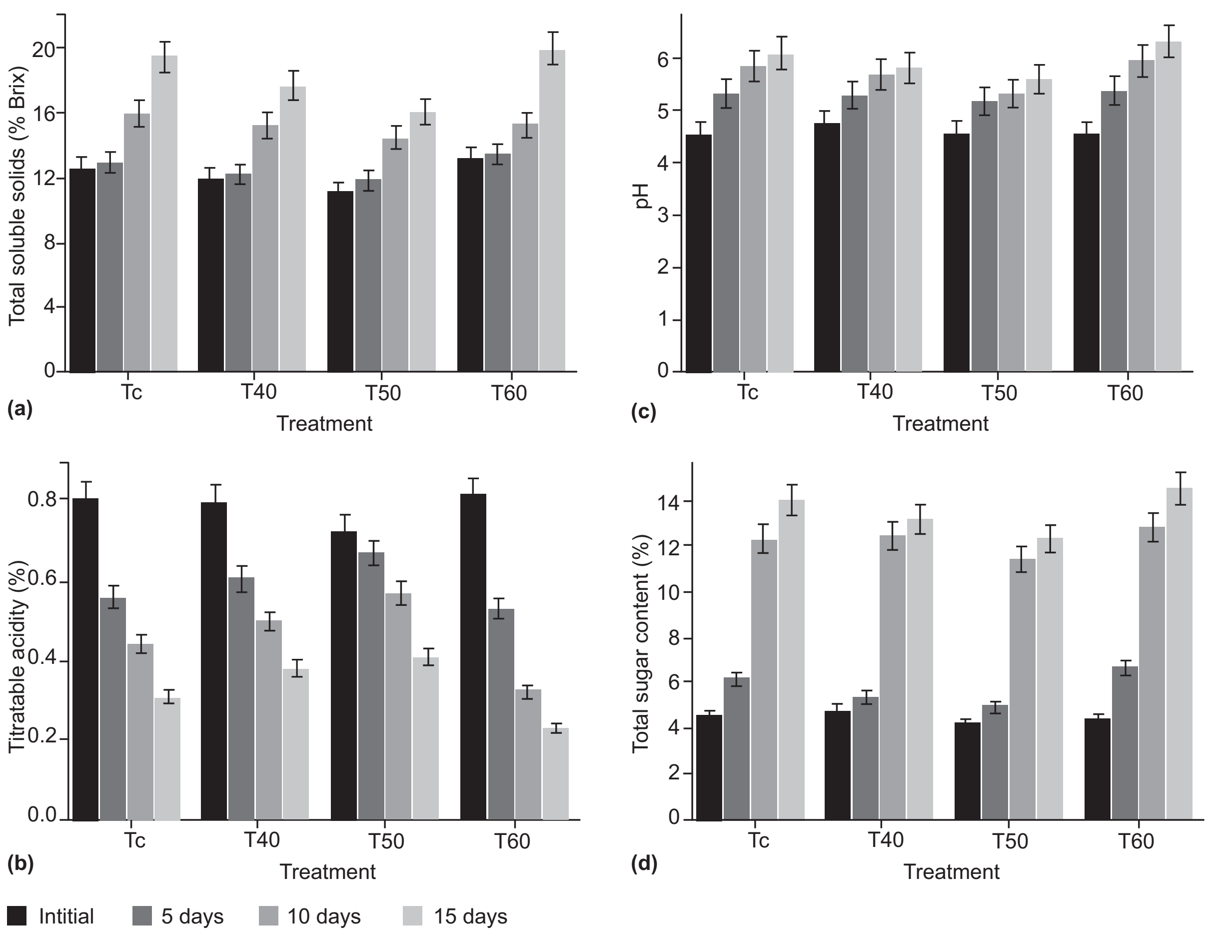


**Fig. 3.** (**a**) Effect of hot water treatments on total soluble solids, (**b**) titratable acidity, (**c**) pH and (**d**) total sugar content.

**Weight loss (%).** An increasing trend for weight loss with respect to storage period was observed for all treatments (Fig. 4c). The results were also found to be statically different as presented in Table 2. The average weight loss for Williams hybrid *(Giant cavendish)* banana fruit was observed to be minimum for $TR_{50}$ (7.12%) where with 8.76% it was highest when treated with $TR_{60}$. The values for weight loss ranged between 5.10 to 15.96%. The respiration rate of fruits during storage accelerated evapouration rate, where burning of tissues resulted greater weight loss (Dharmasena and Kumari, 2005). These findings are in line with the study of Win *et al*. (2007), they reported that the quality of bananas rapidly declines when fully ripened. The same also been reported by Mahajan *et al*. (2010).

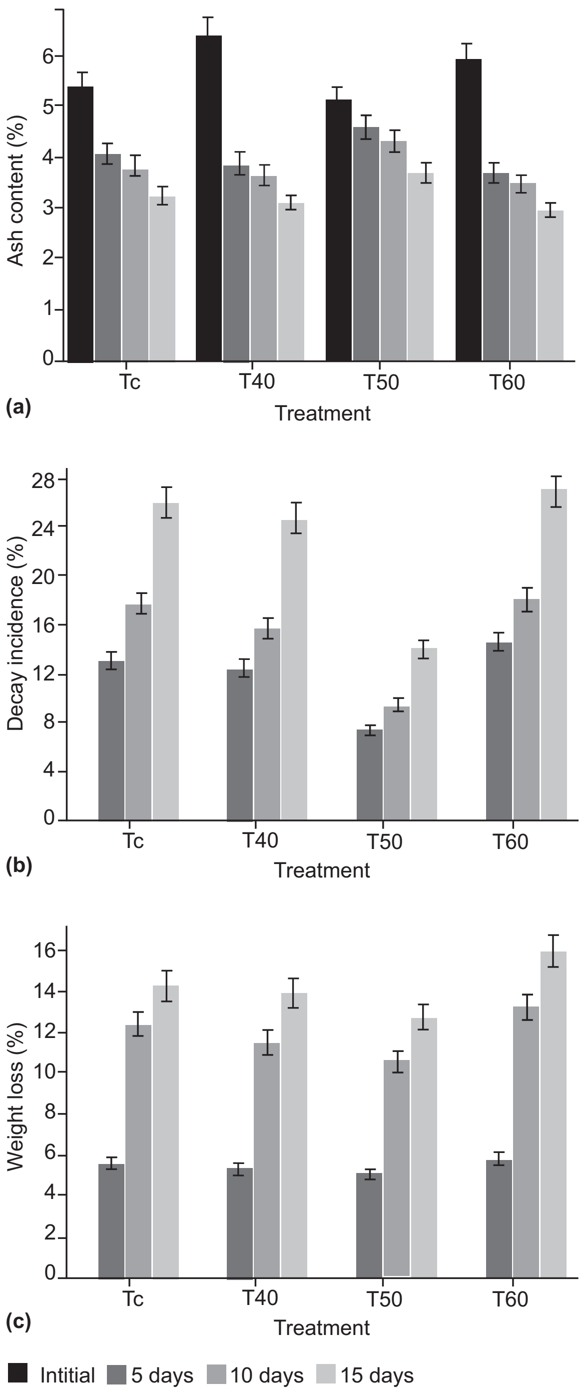


**Fig. 4.** (**a**) Effect of hot water treatments on ash content, (**b**) Decay incidence and (**c**) Weight loss.

## Conclusion

The results of present study concluded with significant effects on physico-chemical properties of Williams hybrid *(Giant cavendish)* banana fruit when treated with different hot water treatments at different storage periods. The average result were obtained to be highest for moisture content (%), fruit pulp firmness (N), pulp to peel ratio, titratable acidity (%) and ash content (%), and lowest for peel color, pulp pH, total sugar content (%), decay incidence (%) and weight loss (%) when treated with 50 ºC hot water. Based on above findings, the adoption of hot water treatment at a temperature of 50 ºC is highly recommended for increasing the shelf life of Williams hybrid *(Giant cavendish)* banana fruit.

**Conflict of interest.** The authors declare that they have no conflict of interest.

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