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Effect of Deficit Irrigation and Storage on Physicochemical Quality of Tomato (*Lycopersicon esculentum* Mill. Var. Pechtomech)

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Abstract
Deficit irrigation is a water saving strategy used to make economic use of water for agricultural activities in order to save water for other purposes. This water deficit may have some negative effects on the quality and postharvest life of the food produced. The aim of this study was to determine the effects of deficit irrigation and postharvest storage on some physicochemical qualities of tomatoes. Tomato fruits (Pectomech variety) cultivated under different irrigation treatments (100% ETc, 90% ETc, 80% ETc and 70% ETc) were harvested and analyzed for firmness, total soluble solids (TSS), titratable acidity (TA) and pH. Firmness was determined by a penetrometer, TSS by hand refractometer, TA by titrating the juice with a standard base (NaOH) and pH by pH meter. Results indicated that firmness, total soluble solids, titratable acidity increased with increasing deficit irrigation while pH decreased. However, these increases and decreases in the parameters with the various water applications were not significant. Titratable acidity of the tomato fruits decreased significantly ($p<0.05$) as storage progressed. Firmness of the fruits decreased while total soluble solids and pH increased with increasing storage period. Considering the percentage increases and decreases in the physicochemical qualities of the tomatoes in this study, it can be concluded that a 10% reduction in the amount or volume of water applied in the cultivation of the Pectomech tomato variety would produce tomato with optimum quality that would compensate for yield losses.
Keywords: Deficit irrigation, firmness, Pectomech, titratable acidity, total soluble solids

1. Introduction

The tomato (Lycopersicon esculentum Mill) is one of the most widely consumed fresh vegetable in the world. Botanically, tomatoes are fruits (berry), but they are commonly referred to as vegetables. Fresh-market tomatoes are a popular and versatile fruit vegetable, making significant contributions to human nutrition throughout the world for their content of sugars, acids, among other constituents. It contains high concentrations of sugars and acids, major contributors to tomato flavor (Gharezi *et al*., 2012).

A lot of pre-harvest activities during cultivation affect the quality and storability of any fruit. Irrigation is a vital agricultural practice that affects both yield and quality of fruits and vegetables. Indeed, irrigation schedule has a great impact on the growth, yield and fruit quality of tomato depending on the amount of water applied (Kere *et al*., 2003). Fruit quality mainly firmness, total soluble solids and acid contents are changed by moisture stress (Vijitha and Mahendran, 2010). Moisture stress not only affects the quality of the fruits but also inhibits crop yield. The major constrain to expand tomato cultivation in the dry zone of Ghana is the variety of environmental stresses such as drought and high temperature. Changes in physicochemical parameters such as total soluble solids (TSS), titratable acidity (TA) and firmness of tomato under water stress have been reported. Shahein *et al.* (2012) reported an increase TSS of tomato under water stress. Abdel-Razik (2012) also reported that firmness and TSS increased and titratable acidity decreased in mango grown under water stress.

Postharvest storage life is defined as the period in which a product should maintain a predetermined level of quality under specified storage conditions (Shewfelt, 1986). A number of chemical and physical processes take place in vegetables during postharvest storage. The physicochemical quality of most fruits and vegetables is affected by water loss during storage which depends on the temperature and relative humidity conditions (Perez *et al*., 2003). Ball (1997) suggested that a postharvest change in firmness can occur due to the loss of moisture through transpiration, as well as enzymatic changes. In addition, hemicelluloses and pectin become more soluble which result into disruption and loosening of the cell walls. Biochemical changes in the fruit during storage may also affect the acid and the total soluble solids content of the fruit. The aim of this study was to establish the effects of deficit irrigation and postharvest storage on firmness, total soluble solids, titratable acidity and pH of tomato (Pectomech variety).

2. Materials and methods

2.1 Sample collection

Tomato samples grown under the various water regimes (100% ETc, 90% ETc, 80% ETc and 70% ETc) were harvested from the School of Agriculture Research Farm, University of Cape Coast and sent to the School of Agriculture Research Laboratory for analysis. Analysis was carried out for physicochemical parameters (firmness, total soluble solids, titratable acidity and pH). All analysis was carried out in triplicates.

2.2 Analysis of physicochemical parameters

The firmness of the tomato fruits was determined with a penetrometer (mod FT 327 (3-27 kg). A handheld refractometer (RHB-32/ATC model) was used to measure the total soluble solids. Titratable acidity was determined by titrating 10 g of the pulp to which 50 ml of distilled water was added and boiled for 30-60 minutes replacing the water lost by evaporation with 0.1M NaOH using phenolphthalein as indicator. The % Titratable acidity was then calculated. pH was measured with a pH meter (Jenway International 3510 pH meter). pH meter was calibrated using a buffer solutions of pH 7 and pH 4.

2.3 Statistical analysis

Results from the study were analyzed using SPSS (Version 20). Descriptive statistics such as mean and standard deviation were also calculated. One way Independent Analysis of Variance (ANOVA) were conducted to measure the significant effect of the different types of irrigation treatment on the various parameters measured. Tukey's HSD multiple comparison was also performed to indicate where the difference exist at $p<0.05$. Simple regression and correlation were conducted to ascertain the relationship between the nutritional components and the amount of water applied.

3. Results and discussions

3.1 Effect of deficit irrigation on physicochemical quality of tomatoes.

The results of firmness of tomato fruits with respect the different water application during cultivation is presented in Figure 3.1. It indicated that the fruits from tomato plant grown under 70% ETc recorded the highest firmness of 7.12 kg with those grown under 100% ETc recording the least firmness of 6.33 kg.

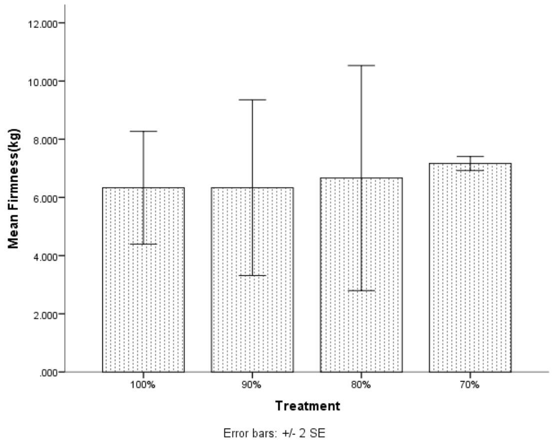

Figure 3.1: Firmness of tomato grown under different water treatment with standard error bars

The firmness of the tomato fruit was in the order 70% ETc > 80% ETc > 90% ETc >100% ETc. This implied that deficit irrigation had a positive effect on firmness of the tomato fruit. Analysis of variance however, revealed that the variation in the firmness of the tomato fruits for the various water applications were not significant (p>0.05). The percentage increases in firmness of the tomatoes with respect to the control (100% ETc) treatment were 5.3%, 2.7% and 14.5 % for the 90% ETc, 80% ETc and 70% ETc respectively.

Firmness is a criterion often used to evaluate fruit quality as it is directly related to fruit development, maturity, ripening and storage potential. It is also related to the likelihood of bruising when fruits are subjected to impact during handling (Lesage and Destain, 1996). Fruit firmness is also an important quality in fruit production that can decide which fruit will be harvested, transported, stored, or marketed. The results of this study showed an increase in fruit firmness with reduction in water application. The firmness of fruits and vegetables is mainly influenced by their moisture contents. Thus the higher the moisture content the lower the firmness and vice versa. Since the moisture content of the tomato fruits from 80% ETc treatment was lower in fruits from 100% ETc and 90% ETc treatments, it is obvious that the tomato fruits form the 80% ETc treatment can have the highest firmness as observed. This result is in agreement with the findings of Proietti and Antognozzi, (1996) on olive and Abdel-Razik, (2012) on mango fruit who reported that increasing irrigation water decreased the fruit firmness and vice versa. The difference in firmness may be due to differences in their pectin composition (Billy *et al.*, 2008).

The results of total soluble solids (TSS) of tomato fruits with respect the different water application during cultivation is presented on Figure 3.2. It indicated that the fruits from tomato plant grown under 70% ETc recorded the highest TSS of 7.50 ^{o}Brix with those grown under 100% ETc recording the least TSS. The TSS of the tomato fruit is in the order 70% ETc > 80% ETc > 90% ETc >100% ETc implying that water stress had a positive effect on TSS of the tomato fruit. Analysis of variance however, revealed the variation in the TSS of the tomato fruits for the various water applications were not significant (p>0.05). From the results the percentage increases in total soluble solids of the tomatoes with the respect to the control (100% ETc) treatment were 4.3%, 5.8% and 8.2 % for the 90% ETc, 80% ETc and 70% ETc respectively.

Total soluble solids (sugar and acid in fruit) are important quality factors for processing tomatoes. It is the measure of the mass ratio of dissolved sucrose to water in the fruit. The results of this study showed an increase in total soluble solids with reduction in water application. This result is in agreement with the findings of Shahein *et al.*, (2012) and Tuzel *et al.*, (1993), who reported that increasing the rate of irrigation of greenhouse tomato plant can lead to a reduction in soluble solids. The difference in total soluble solid of the different water treatments was due to difference in water content of the fruits (Abdel-Razik, (2012).

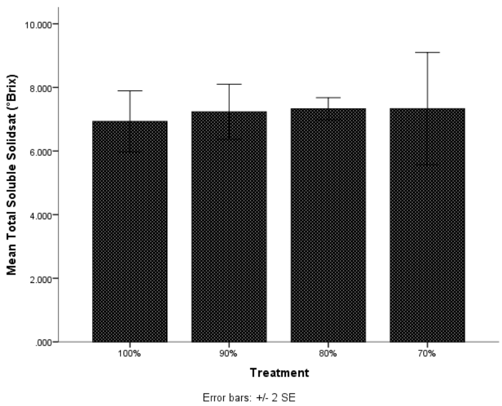

Figure 3.2: Total soluble solids content of tomato grown under different water treatments with standard error bars

This implied that reduction in the amount of water used to irrigate the tomato plant led to a reduction in the moisture content of the fruit and hence increasing the total soluble solids content of the fruits. Tomato fruits with high total soluble solids are desirable especially if the tomato fruits are to be used for processing into tomato products such as puree, paste and ketchup.

The titratable acidity of the tomato as indicated in Figure 3.3 showed a trend of increasing with respect to water stress with mean values ranging from 0.93% for 100% ETc and maximum of 1.06% for 70% ETc. However, the differences in the titratable acidity of the tomato for the different water applications were not significant (p>0.05). Thus the treatment did not have any significant effect on the titratable acidity of the tomato. From the results the percentage increases in titratable acidity of the tomatoes with the respect to the control (100% ETc) treatment were 8.6%, 11.8% and 14.0 % for the 90% ETc, 80% ETc and 70% ETc respectively. This implied that tomato fruits from 70% ETc treatments produced fruits with higher acid content. This is desirable since high acid and high sugar contents produce best flavoured tomato fruits (Stevens *et al*., 1977).

The mean value for the pH was within the range 4.30-4.47, with 100% ETc treatment recording the highest and 70% ETc treatment recording the lowest (Figure 3.4). It was observed that the pH of the tomatoes increased with increasing water treatment. The results indicated that the pH of the tomatoes was in the order 100% ETc > 90% ETc > 80% ETc > 70% ETc. However, these differences in the pH values of the tomato were not significant (p>0.05) with respect to the different water applications.

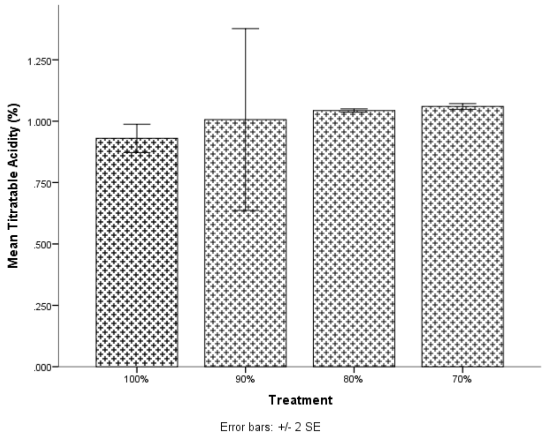

Figure 3.3: Titratable acidity of tomato grown under different water treatments with standard error bars

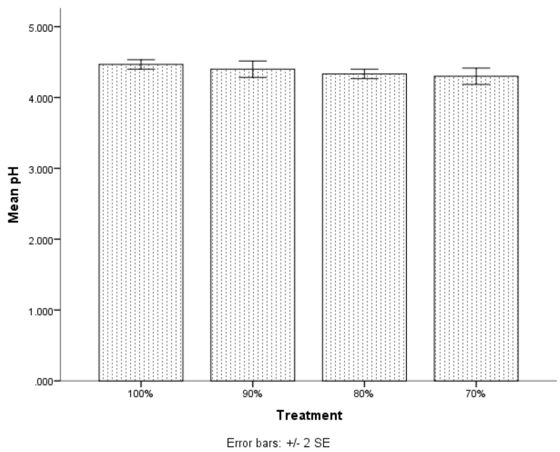

Figure 3.4: pH of tomatoes grown under different water treatments with standard error bars

Titratable acidity and pH are two quality characteristics of tomato fruit. The pH of tomato is determined primarily by the acid content of the fruit. Organic acids are the major taste components in tomatoes. Sugars, acids and their interactions are important for sweetness, sourness and overall flavor intensity in the tomato that contribute to the taste (Kader, 2008).

An increase in the titratable acidity content of the fruit was observed when the plants were subjected to water stress. This agrees with the study conducted by Pantane *et al.,* (2011) who reported that the tritratable acidity and vitamin C contents were increased under water stress (50% ETc) compared to a full irrigation water treatment (100% ETc). Rouphael *et al.,* (2008) also illustrated that water stress can improve quality in fruits and explained further that when tomato plants are irrigated with less water, the plant regulate certain metabolic activities, such as osmotic adjustment in sink organs, to increase the sucrose and organic acid transformation rate and amount, consequently more assimilates shift to the fruits, thus improving soluble sugar, total soluble solid and acidity content. This implied that tomato fruits from plants treated with less water had low pH values which would lead to improvement in the flavour of the fruits.

3.2 Effect of storage on physicochemical quality of tomato grown under different water treatments

The results showed a gradual decrease in firmness of the tomato for the water treatments across the storage period for all treatments except for treatment 90% ETc which recorded a slight increase in firmness on day 5 thereafter decreased gradually till day 20 (Figure 3.5). There were no significant differences ($p>0.05$) in the firmness of the tomato for treatments 100% ETc, 90% ETc and 80% ETc across the storage period from day 0 to day 20. However, there were significant differences ($p<0.05$) in the firmness of the tomato for treatment 70% ETc during storage. The changes in the firmness of the tomato from day 0 to day 20 of storage were 6.33-4.10 kg, 6.67-3.60 kg, 6.50-4.37 kg and 7.25-3.78 kg for the 100% ETc, 90% ETc, 80% ETc and 70% ETc respectively.

The most important factor next to visual appearance in tomato quality is firmness which is closely associated with ripeness stage. Most consumers prefer firm fruits which do not lose too much juice when sliced and which do not have tough skins. Firmness affects susceptibility of tomatoes to physical damage and consequently their shipping ability (Raffo *et al*., 2002). The textural quality of tomatoes is influenced by skin toughness, flesh firmness, and internal fruit structure which vary greatly among cultivars. All fruit softened progressively during storage, firmness of tomato was influenced by storage time. The reduction in firmness of the tomato fruits during storage may be due to high respiration rate and loss of water leading to weight loss. This implied that as tomato fruits were stored they lost their firmness which is an undesirable effect as far as quality of the fruit is concerned.

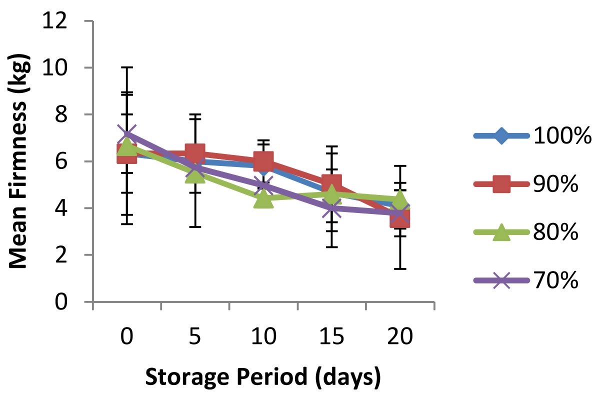

Figure 3.5: Effect of storage on firmness. Vertical bars represent standard error of the mean

The result presented in Figure 3.6, clearly showed that there were gradual increases in total soluble solids of the tomatoes for the different water treatments during the storage period. However these increases were not statistically significant ($p>0.05$). Among the treatments, 80% ETc treatment recorded the highest TSS (9.87°Brix) and 100% ETc recorded the lowest TSS (8.62°Brix) at the end of storage. The total soluble solids acts as a rough index of the amount of sugars present in fruits. It is the amount of sugar and soluble minerals present in fruits and vegetables. Sugars constitute 80-85 per cent of soluble solids. The total soluble solids increased during ripening due to degradation of polysaccharides to simple sugars thereby causing a rise in TSS (Gharezi *et al*., (2012). Most fruits and vegetables lose moisture during storage. The decrease in moisture leads dehydration which might result in the increase the total soluble solids. High moisture content of fruits leads to less soluble solids (Brooks and MacGilivray, 1928). The increase in total soluble solids of the tomato fruit during storage is desirable since it may lead to an increase in the sugar content hence improving the sweetness and general flavour of the fruit.

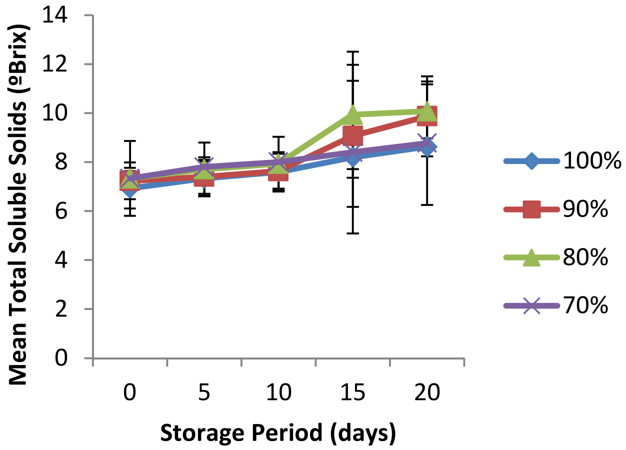

Figure 3.6: Effect of storage on total soluble solids. Vertical bars represent standard error of the mean

From figure 3.7 it is observed that the titratable acidity for all the various treatments decreased across the storage period. Analysis of variance indicated that the different treatments had significant effects ($p<0.05$) on the titratable acidity of the tomatoes during storage. The changes in the titratable acidity of the tomato from day 0 to day 20 of storage were 0.93-0.45%, 1.01-0.52%, 1.04-0.67% and 1.06-0.68% for the 100% ETc, 90% ETc, 80% ETc and 70% ETc respectively. The decline in titratable acidity with increase in pH of the tomato fruits during storage is inevitable because during ripening, acids are converted into sugars.

The results showed that within 70% ETc treatment, the decreased in titratable acidity across storage from day 0 to day 15 of storage was not significant ($p>0.05$). However, there was a significant difference in the titratable acidity of the tomato at day 20 of storage. Comparing 100% ETc treatment which is the control treatment to the other treatments, there were mean differences in the acid level, but analysis of variance indicated these differences were significant ($p>0.05$).

The decrease in the titratable acidity of the tomato during storage can also be attributed to the fact that the amount of organic acid in the fruit decreased during maturity because they are substrates of respiration. During ripening of tomato, malic acid disappears first, followed by citric acid resulting in reduction in amount of acidity (Salunkhe *et al.,* (1974). This suggests that there is catabolism of citrate via malate and also that the microorganisms may use citric acid as a carbon source hence resulting in reduction in titratable acidity. The decline of acidity may also be attributed to increase activity of citric acid glyoxylase during ripening which may lead to the conversion of the acids into sugars and further utilization in metabolic process during storage (Rathore *et al*., 2007). The decrease in the titratable acidity of the tomato fruits during storage may negatively affect the flavour of the fruit since high acid coupled with high sugars produces good flavours in tomato fruits.

The results presented in Figure 3.8 showed that pH increased during storage for all the water treatments. Statistically, these differences in the pH values of the tomato fruits were not significant ($p>0.05$). The changes in the pH of the tomato from day 0 to day 20 of storage were 4.47-4.50, 4.40-4.55, 4.33-4.47 and 4.30-4.34 for the 100% ETc, 90% ETc, 80% ETc and 70% ETc respectively.

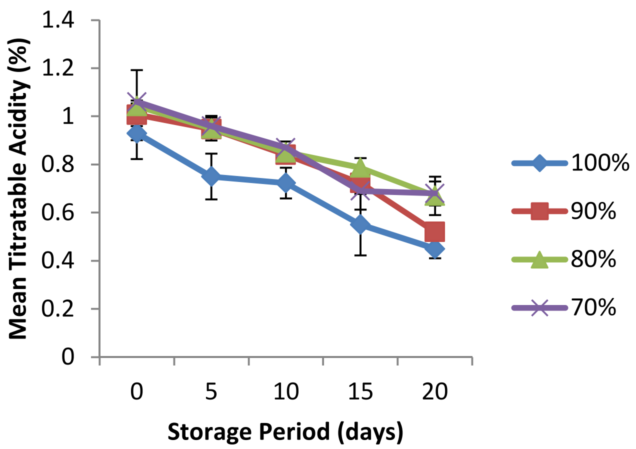

Figure 3.7: Effect of storage on tritratable acidity. Vertical bars represent standard error of the mean

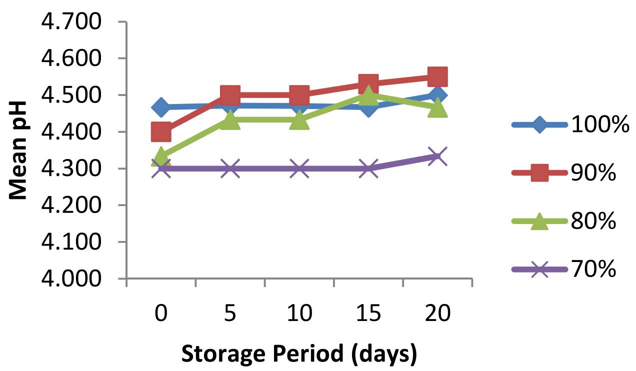

Figure 3.8: Effect of storage on pH. Vertical bars represent standard error of the mean

This increase in pH of the tomato fruits may be due conversion of the citric acid into sugars during storage resulting in the tomato fruit becoming less acidic (Rathore *et al*., 2007). The increase in the pH of the tomato fruits during storage may negatively affect the flavour of the fruit since it indicated a reduction in acidity of the fruits. It has been reported that high acid coupled with high sugars produces good flavours in tomato fruits (Stevens *et al.*, 1977)

4. Conclusion

Based on the results obtained from this study, it can be concluded that deficit irrigation has both positive and negative effects on the physicochemical quality of the tomato fruits. Deficit irrigation caused increases in firmness, total soluble solids, titratable acidity of the tomato fruits. However, a decrease in pH of the tomato fruits with decreasing water applications was recorded.

The firmness of the tomato fruits decreased across the storage period for all water treatments with the 80% ETc treatment recording the highest firmness, followed by 100% ETc, then 70% ETc and the lowest by 90% ETc treatment at the end of storage.

In all water treatments there were increases in the total soluble solids of the tomato fruits during storage. At the end of storage, the tomato fruits from 80% ETc treatment had the highest total soluble solids, followed by 90% ETc, then 70% ETc and finally by 100% ETc treatment. Once again, the moisture content of the tomato fruits at the end of the storage influenced the total soluble solids of the tomato fruits.

As titratable acidity of the tomato fruits decreased, pH of the fruits increased during storage for all treatments. This is inevitable because reduction in acidity leads to increase in pH. However, storage had significant effect titratable acidity but had no significant effect on pH of the tomato fruits.

Considering the percentage increases and decreases obtained for physicochemical quality of the tomatoes in this study, it can be concluded that a 10-20% reduction in the amount or volume of water applied in the cultivation of the Pectomech tomato variety in the coastal savannah zone of Ghana would produce tomato with optimum quality that would compensate for yield losses.

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