CHANGES IN QUALITY OF PAWPAW (Carica papaya) FRUIT DRIED UNDER DIFFERENT PRETREATMENTS AND DRYING METHODS

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ABSTRACT

In this work the effect of pretreatments and drying methods on some qualities of dried pawpaw fruits were studied. The fruit slices were pretreated with three pretreatments – ascorbic acid dip at 31 % w/v concentration, honey dip at 20 % v/v concentration and steam blanching at a temperature of 120 oC and dried using three drying methods (sun, solar and oven drying). Sliced pawpaw fruits were soaked in the prepared solutions for 4 minutes, while the blanching was done for 2 minutes. There were control samples for each drying method. The samples were dried using the three drying methods until safe moisture content of below 6% was achieved. The safe moisture content was achieved for sun, solar and oven drying methods after drying the sample for 6, 8 and 9 hours at an average temperature of 32 oC, 41 oC and 65 oC respectively. Drying curves were generated and the drying rate, proximate composition, vitamin C and β-carotene contents of the dried fruits were determined. The result showed that pretreatment methods used did not have effect on the drying rate however it has a significant effect on retention of nutrient. The fat, protein, ash and fiber contents are higher in pretreated samples compared to the control. The nutrient analysis showed that pawpaw samples treated with honey solution and oven dried had the highest vitamin C content (116.05mg/100g), while ascorbic acid treated and oven dried samples had the highest value for β-carotene content (12677.35µg/100g) The composition of the pretreated dried pawpaw samples revealed that they are rich in vitamin C and β-carotene (antioxidant) which makes them healthy and nourishing and also important ingredient in the food industry for the production of food supplements and other functional foods.

Keywords: Pawpaw, pretreatments, drying methods, qualities, vitamin C and β-carotene

INTRODUCTION

Pawpaw (Carica papaya L.) is grown extensively in all tropical and sub-tropical parts of the world. It has been regarded as one of the most valuable tropical fruits that contain β-carotene, protein, carbohydrate, vitamins and minerals (Nurul et al., 2017). Snake and Desmond (2009) reported that mature green pawpaw fruit contains more vitamin A than carrots, more vitamin C than oranges, abundant vitamin B and vitamin E. Pawpaw can be used for various purposes such as food, cooking aid and in medicine (Ray, 1994). The growing demand for such healthy diets results in increasing demand for fresh, processed and semi-processed pawpaw. However, pawpaws are seasonal fruits and due to the perishable nature of the fruit, its availability in fresh form is limited. Ripe pawpaw contains about 80% moisture; they are very susceptible to post-harvest losses and considerable weight loss during transportation and storage. This in turn leads to high economic losses as a result of reduction in weight and quality. It is therefore of great importance to preserve these fruits for a longer period, and this is made possible through drying and/or dehydration to reduce the moisture to the possible minimum level. Thus, one of value-adding methods to pawpaw is
drying to produce dried products in forms of cubes, chips, strips, etc (Kraipat et al., 2010). Drying is one of the oldest methods for the preservation of food products and it is the process of removal of water from food items to reduce the moisture content to a level which prohibits the growth of microorganism and improve the quality and durability of foodstuffs. It is a thermo-physical action and its principles are governed by heat and mass transfer laws inside and outside the product. Conventional dehydration processes commonly used for fruit drying includes hot-air drying, sun drying, solar drying and freeze drying. Drying may cause changes in product quality the level of which may vary depending on the method of drying. Pretreatment often proceed drying of fruit and vegetable in order to minimize the adverse changes occurring during dehydration and subsequent storage. It is a recommended technique used to make quality products. Odewole et al. (2014) studied the effects of pre-drying treatments and drying conditions on drying rate and quality attributes of mango chips. Their result shows that that all the process conditions considered were significant on drying rate and quality attributes of mango chips. The effect of different pretreatments on the quality attributes of air dehydrated pineapple slices was investigated by Karim et al. (2008). They used sucrose, blanching and sulphiting methods of pretreatment on pineapple slices. The result revealed that the pretreatments used had a significant effect on the quality attributes of the samples. This study was carried out to investigate the effect of pretreatments (ascorbic acid dip, honey dip and steam blanching) and drying methods (sun, solar and oven) on some quality parameter of dried pawpaw.

MATERIALS AND METHODS
Fresh ripe pawpaw fruit were procured, from the local fruit market in Minna, Niger State of Nigeria. The ascorbic acid and honey for the pretreatments were bought from Mudos Pharmaceuticals, Minna, Nigeria. Other materials and equipment used include air-circulated oven (Genlab, England model PBS11SF), a box solar dryer, wooden trays with net for sun drying, steamer pot, weighing balance (Ohaus, AR3130, China, 0.001 g), measuring cylinder, rule and calipers, cutting trays and boards, knives, bowls, hand gloves and towels. The solar dryer was constructed in the department of Agric and Bioresources Engineering, Federal University of Technology, Minna. It is a direct solar box dryer which consists of a wooden cabinet, a glass cover and trays on which the treated sliced fruit were placed. The glass cover is inclined by 30° for maximum exposure to the sun and to allow movement of air through buoyancy. The interior of the dryer was painted black for maximum collection of solar rays.

2.1 Pretreatments
The pawpaw fruits were inspected, sorted and only sound fruits without any physical damage were selected for the experiment. The selected fruits were washed, hand-peeled and cut into about 5 mm thick slices for quick drying. The initial moisture content and initial weight of the fruit samples were determined. The sliced pawpaw fruits were divided into 400 g each and treated with steam blanching (SB), ascorbic acid solution dip (AAD) and honey solution dip (HD) before drying; one sample was untreated and served as the control. For steam blanching, the sliced fruit samples were placed in a steamer pot in a thin-layer and put over boiling water at 120°C for two minutes. The fruit was covered tightly to allow circulation of the steam and afterward cooled, drained and dried immediately. For the ascorbic acid dip pretreatment, 300 g of ascorbic acid was mixed with 660 mL of distilled water to form 31% v-v ascorbic acid solution according to the method used by Abano and Sam-Amoah (2011). Fruit slices were soaked in the solution for four minutes, drained well and placed on trays for drying while in honey dip; honey-water solution was prepared using one part of honey to four parts of water to form 20% v-v solution (Andress and Harrison, 2006). The fruits were dipped into the solution immediately after slicing and left for four minutes and then drained well before drying.

2.2 Drying Methods
Three drying methods were used in the experiments which are sun drying, solar drying and oven drying. Sun drying of the fruits was carried out by placing the treated sliced fruits
on drying trays in a thin layer. The trays were placed on a raised platform and left in the sun to dry. The raised platform enables adequate air circulation around the fruit; the average temperature during drying was 32°C. For the oven drying the oven was preheated before the fruit were placed into it and the temperature was set to 65°C.

In the solar drying the pretreated samples were arranged on trays in thin layer and kept inside the solar dryer. Then, the dryer was kept under the sun and solar rays were trapped with the help of the solar collector, the average temperature in the solar dryer was 41°C. During the experiment all the samples were weighed at an interval of one hour until a constant weight was obtained. Temperature in the solar dryer and the ambient temperature were also monitored regularly. The experiment was carried out in the Agricultural and Bioresources Engineering departmental laboratory, Federal University of Technology, Minna, Nigeria.

2.3 Proximate and Vitamin Analysis

Proximate values for moisture, fat, protein, ash, and crude fiber of dried fruit samples were determined according to AOAC (1990); carbohydrate content was calculated by difference, vitamin C and β-carotene contents of dried fruit samples were determined by titration method of Osborne and Voogt (1978) and spectrophotometric method based on Ultraviolet (UV) inactivation respectively as described by Onwuka (2005).

2.4 Sensory evaluation

A 5-member panelist consisting of 3 male and 2 female postgraduate students evaluated the dried pawpaw samples for organoleptic properties (odour, taste, texture and overall acceptability). A 5 point hedonic scale (with 5 = like very much and 1 = dislike very much) were used (Richard et al., 2013 and Abano et al., 2013)

2.4 Drying Rate Determination

Drying rate is the rate of moisture removal per time during the drying process. It was obtained by determining the moisture content of samples as drying progresses Odewole et al. (2014). Mathematically it is expressed as:

\[ DR = \frac{w_1 - w_2}{t} \]

Where, \( w_1 \) = Weight of product before drying (g); \( w_2 \) = Weight of product after drying (g); \( t \) = Drying time (h); \( DR \) = Drying rate (g h\(^{-1}\)).

2.5 Statistical Analysis

The experimental runs were conducted in triplicate. Analysis of variance (ANOVA) was done at significance level of 0.05 using the IBM statistical package SPSS 20.0. Mean differences in the treatments were tested for significance using the Duncan Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

3.1 Drying curves

The drying curves for drying of pawpaw slices under different drying methods and pretreatment are shown in Figures 1 - 4, where the moisture contents of the samples were plotted against various time intervals and for different drying methods. Pawpaw having 90 % initial moisture content was dried to a range of final and safe moisture content of below 6%. Drying was carried out within 6, 8 and 9 hours for oven, solar and sun drying methods respectively. The variation in drying temperature is due to the temperature difference in the various drying methods. The average temperature in the sun and solar drying was 32°C and 41°C respectively while in the oven dryer the temperature was set to 65°C. The drying curves are similar to those gotten by Kaddumukasa et al., (2005) where they examined the effect of drying methods on the quality of green banana flour; Jokić et al. (2009) on apple samples and Nurul et al., 2007 for pawpaw. Figure 5 shows the drying rate for all the drying methods and all the treatments. From the figure it can be seen that pretreatments before drying did not have effect on the drying rate.
Figure 1: Drying Curves of Dried Mango Samples for the Three Drying Methods
(Control)

Figure 2: Drying Curves of Dried Mango Samples across the Three Drying
Methods (AAD treatment)
Figure 3: Drying Curves of Dried Mango Samples for the Three Drying Methods (HD treatment)

Figure 4: Drying Curves of Dried Mango Samples for the Three Drying Methods (SB treatment)
Figure 5: Drying rate for the three drying method and all the treatments

Table 1: Proximate Composition of Dried Pawpaw

| Pretreatment methods | MC (%) | Fat (%) | Protein (%) | Ash (%) | Fibre (%) | Carbohydrate (%) |
|----------------------|--------|---------|-------------|---------|-----------|------------------|
| **Sun** control      | 5.00a  | 7.00ab  | 2.03a       | 2.50a   | 8.61a     | 74.00b           |
| AAD                  | 5.50a  | 7.50bc  | 2.39ab      | 3.00ab  | 8.79a     | 73.18a           |
| HD                   | 5.50a  | 7.50bc  | 2.36ab      | 3.00ab  | 8.92a     | 73.22a           |
| SB                   | 5.00a  | 8.00c   | 2.30a       | 3.50b   | 8.96a     | 72.24a           |
| **Solar** Control    | 5.00a  | 6.50a   | 1.78a       | 2.50a   | 8.98a     | 74.64b           |
| AAD                  | 4.50a  | 7.00a   | 2.09a       | 2.50a   | 9.14ab    | 75.27b           |
| HD                   | 4.50a  | 5.00a   | 2.03a       | 2.50a   | 9.02a     | 76.95b           |
| SB                   | 5.00a  | 7.00a   | 1.93a       | 3.50b   | 9.08ab    | 73.59a           |
| **Oven** Control     | 5.00a  | 6.00a   | 2.02a       | 2.00a   | 9.01a     | 74.35b           |
| AAD                  | 4.50a  | 7.50bc  | 3.85b       | 3.00ab  | 9.19b     | 73.46a           |
| HD                   | 4.50a  | 6.00a   | 2.14a       | 3.50b   | 9.61b     | 74.34b           |
| SB                   | 5.00a  | 8.00c   | 2.77b       | 2.50a   | 9.64b     | 72.12a           |

Values followed by the same letter in the same column are not significantly different at P < 0.05

3.2 Proximate Composition of Dried Pawpaw

The proximate compositions of dried pawpaw samples determined by standard laboratory procedures are shown in Table 1. The result shows that there is a significant difference (p < 0.05) in the fat, protein, ash, fiber and carbohydrate contents among the treatments and drying methods but, no significant difference was observed in the moisture content. It can be concluded that pretreatment and drying methods have effect on the proximate composition of dried pawpaw. The results of the moisture content were similar to those obtained by Ojike et al. (2011). It was also observed that nutrient retention is highest
in all the pretreated samples. Odewole et al. (2014) obtained similar result during osmotic dehydration of mango slices. Steam blanched samples have high fat and fiber content for all the drying methods and high ash content for sun and solar dried samples. For all the treatment carbohydrate is highest in solar and oven dried samples.

3.3 Vitamin C and β-Carotene Contents of Dried Mango.

Vitamin C and β -Carotene are very important component of fruits. Vitamin C and β – Carotene content of dried pawpaw fruit is shown in Table 2. The result shows that the pretreatment and drying methods did not have any effect on β-carotene content but it has on the vitamin C content. Vitamin C content was higher in ascorbic acid and honey treated samples than in the control and steam blanched ones for the different drying methods. This may be due to the additional vitamin C content in the acid and honey. These values are higher than those obtained by Karim (2010) for pineapple.

3.4 Sensory Evaluation of pawpaw samples

The result of the sensory evaluation is shown in Table 3. The result shows that for sun dried pawpaw samples there were no significance difference at $p < 0.05$ for all the properties studied. For solar and oven dried samples there is significant difference at $P<0.05$. Solar dried honey treated sample has the highest score for odour. In terms of taste, oven dried ascorbic acid treated sample has the highest score of 4.0 while the solar steam blanched sample has the lowest score of 2.2. For overall acceptability, sun dried ascorbic acid treated and oven dried control samples score the highest. Generally, for all the treatments the quality index obtained was well above average values. Abano et al. (2013) obtain similar result for dried mango samples.

Table 2: Vitamin C and β -Carotene Contents of Dried Pawpaw

| Samples   | Vitamin C (mg/100g) | β-Carotene (µg/100g) |
|-----------|---------------------|----------------------|
| **Sun** control |                     |                      |
| AAD       | 103.20<sup>b</sup>  | 10174.90<sup>b</sup> |
| HD        | 107.00<sup>b</sup>  | 10326.14<sup>b</sup> |
| SB        | 111.80<sup>b</sup>  | 10272.45<sup>b</sup> |
| SB        | 104.50<sup>b</sup>  | 10198.48<sup>b</sup> |
| **Solar** control |                 |                      |
| AAD       | 81.50<sup>a</sup>   | 8071.41<sup>a</sup>  |
| HD        | 98.90<sup>a</sup>   | 8310.71<sup>a</sup>  |
| SB        | 111.80<sup>b</sup>  | 8196.10<sup>a</sup>  |
| SB        | 90.80<sup>a</sup>   | 8020.10<sup>a</sup>  |
| **Oven** control |                |                      |
| AAD       | 77.02<sup>a</sup>   | 12311.28<sup>a</sup> |
| HD        | 98.90<sup>a</sup>   | 12677.35<sup>a</sup> |
| SB        | 116.05<sup>c</sup>  | 12648.18<sup>a</sup> |
| SB        | 109.02<sup>b</sup>  | 12301.92<sup>a</sup> |

Values followed by the same letter in the same column are not significantly different at $P < 0.05$. 
Table 3: Sensory Evaluation of Dried Pawpaw

| Samples       | Odour  | Taste  | Texture | Overall acceptability |
|---------------|--------|--------|---------|-----------------------|
| **Sun control** | 3.6a   | 3.6a   | 3.2a    | 3.6a                  |
| AAD           | 3.8a   | 3.6a   | 3.6a    | 4.0a                  |
| HD            | 3.8a   | 3.6a   | 3.6a    | 3.8a                  |
| SB            | 3.8a   | 3.4a   | 3.4a    | 3.8a                  |
| **Solar Control** | 3.6b   | 3.6c   | 3.0a    | 3.8a                  |
| AAD           | 3.6b   | 3.2b   | 3.4b    | 3.6a                  |
| HD            | 4.0c   | 3.8c   | 3.4b    | 3.8a                  |
| SB            | 3.2a   | 2.2a   | 3.0a    | 3.8a                  |
| **Oven Control** | 3.4a   | 3.2a   | 3.4a    | 4.0a                  |
| AAD           | 3.8b   | 4.0c   | 3.8b    | 3.4a                  |
| HD            | 3.8b   | 3.6b   | 3.4a    | 3.6a                  |
| SB            | 3.8b   | 3.4ab  | 3.2a    | 3.6a                  |

Values followed by the same letter in the same column are not significantly different at P < 0.05

CONCLUSION

Dried fruits when compared to their fresh counterparts have valuable nutritional, antioxidant, and health-promoting properties and are good alternatives especially during the off season. These experiments were carried out to investigate the effect of pretreatments and drying methods on the quality of dried pawpaw. The fruits were dried using three different drying methods (sun, solar and oven drying methods) and pretreatments (ascorbic acid dip, honey dip and steam blanching). There was also a control sample. The drying rate, proximate composition, vitamin C and β-carotene contents and some organoleptic properties of the dried fruits were determined and the results showed that there was higher retention in the nutrient of the pretreated dried pawpaw samples compared to the control sample. Honey treated samples had the highest retention of vitamin C (Which is a major nutrient in dried pawpaw) when compared with the ascorbic acid treated samples, steam blanched and control samples for all drying methods. Therefore, honey solution is recommended as a good and healthy pretreatment for dried pawpaw. Alternatively, ascorbic acid solution can be used since it enabled a good retention of vitamin C content in dried pawpaw. However, for maximum benefit various concentrations of the two solutions should be further investigated.

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THE EFFICACY OF POSTHARVEST BIOCONTROL TREATMENTS IN CONTROLLING SPOILAGE OF TOMATO FRUIT IN SOUTH AFRICAN COMMERCIAL SUPPLY CHAINS

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ABSTRACT

In this study, the effectiveness of postharvest biocontrol treatments using B-13 yeast isolate in controlling spoilage of tomato fruit was evaluated in selected commercial supply chains in South Africa. Mature green tomatoes were harvested from three commercial farms in Limpopo (Musina, Mooketsi and Pont drift) during summer and transported through the three supply routes to Pietermaritzburg, where four postharvest treatments were applied to the fruit, then stored in ambient and cold storage (11°C) conditions. The fruit was sampled over a 30-day storage period and its firmness, colour, weight loss, marketability and incidences of decay assessed. Fruit stored under ambient conditions had higher incidences decay, diseases and physiological disorders compared to samples stored in cold storage, with these incidences varying widely with pre-storage treatments applied on the fruit. The supply chain route significantly (p≤0.05) influenced the physicochemical and subjective quality of tomato fruit. Biocontrol treatment reduced mass loss of fruit and had comparable physicochemical and subjective attributes to chlorine treated fruit. Biocontrol treatment was also effective in maintaining fruit firmness and colour for the first eight days of storage. Biocontrol treated fruit had 7.9% and 7.7% lower mass loss compared to control and chlorine fruit treated fruit, respectively. Although, biocontrol treatment showed promising prospects in controlling tomato spoilage and improving its shelf life, integrating it with other treatments should be further tested to improve its efficacy.

Keywords: pre-storage treatments, supply route, tomato spoilage, B-13 biocontrol, yeast isolate

INTRODUCTION

Tomatoes are some of the most widely consumed fresh fruits globally whose popularity is only second to potato (Dorais, et al., 2008). Fresh tomatoes play an important culinary role in many cultures worldwide, and in this way, enjoy a global appeal to meal preparation (Beckles, 2012). Tomatoes are also used to prepare salads, salsa or processed into juices (Pinheiro, et al., 2014). Its consumption is associated with the prevention of degenerative health conditions including cardiovascular diseases and certain forms of cancers, as it is rich in antioxidants and other health promoting compounds (Canene-Adams, et al., 2005).

In South Africa, the tomato industry is one of the most important sources of fresh fruit and vegetables (FFV), and a valuable contributor to the national gross domestic product (DAFF, 2013). In 2015, it is estimated that tomato production in South Africa was 56 6180 metric tons (FAOSTAT, 2015), and has been increasing for the last decade (DAFF, 2013). By the end of 2014, the South African tomato industry was valued to be over 2 billion rand (DAFF, 2015).

Although the production of tomatoes has been increasing over time, it is widely reported that postharvest losses of fresh tomatoes are comparatively among the highest globally, especially in emerging markets. In some
regions of Africa, postharvest losses of tomato fruit have been reported to be as high as 40% (Moneruzzaman, et al., 2009). These losses are linked to the physiological nature of the fruit. Deteriorative physiological processes such as respiration, transpiration and catabolic enzymatic breakdown of cellular structures continually occur in the fruit even after harvest (Tigist, et al., 2013). Temperature management is one of the key approaches used to slow down these processes (de Castro, et al., 2005). Tomato fruit is also a high moisture food rich in sugars and other nutrients, making them an attractive host for a broad spectrum of pathogenic and spoilage microorganisms (Dugassa, et al., 2015). For this reason, the applications of disinfection treatments that control microbial contamination are important in controlling the incidence of decay and proliferation of spoilage microorganisms on tomato fruit.

Chemical disinfectants such as chlorinated water are the standard sanitizers used globally in the tomato industry. Some of these chemical disinfectants are environmental pollutants and have perceived health concerns from an increasingly health conscious global consumer population, besides triggering post-harvest disorders on the fruit (Venta, et al., 2010). Alternatives to these chemical disinfectants should therefore, be developed.

Bioctheatrical agents have the potential of competitively controlling pathogenic and spoilage microorganisms in fruits (Liu, et al., 2010). In the South African citrus industry, a yeast isolate, B-13 is registered for use in controlling postharvest spoilage in citrus. Bioccontrol agents are however, currently not in use commercially in the South African tomato industry. As a preliminary study, this work tests the effect of the B-13 yeast isolate used for citrus on some of the quality parameters of fresh tomatoes. It therefore purposes to lay ground for future research in the use of bioccontrol agents in controlling spoilage of tomatoes under South African conditions.

MATERIALS AND METHODS

Tomato samples

Tomato fruit of Nimmo-Netta variety was harvested at green maturity stage in three commercial farms located in Limpopo province, South Africa. The farms were located in Esme four (ZZ), Mooketsi (EM) and Point drift (PD) a distance of 1158, 934 and 894 km, respectively from Pietermaritzburg. The fruit was transported using trucks from their respective farms to Pietermaritzburg, typifying supply and distribution of tomato fruit under commercial conditions.

Experimental design

Upon receiving the samples in Pietermaritzburg, they were immediately taken to University of KwaZulu-Natal’s Bioresources Engineering lab, where 4 pre-storage treatments were applied on them and stored under ambient or cold storage conditions (11°C). These pre-storage treatments involved dipping the fruit in; hot water (42.5°C for 30 min), Biocontrol using B-13(1g. l-1 for 30 sec), control (tap water) and chlorinated water (100 ppm for 20 min). The experiment was arranged in a factorial experimental design. All treatments were replicated thrice.

Data collection

Fruit quality parameters was assessed briefly as follows: Fruit colour was measured using a Minolta Chroma meter (Model CR-400, Narachi Pty, South Africa) at an observer angle of 2° after standardizing the instrument with a white tile (Y=93.8, X= 0.3030, y=0.3191). Illuminant C was used to measure the L*a*b*c and h values, where two readings were done from six fruits, for each treatment (Pinheiro, et al., 2015). Fruit firmness was measured using Instron universal testing machine (model 3345, Advanced Laboratory Solutions, South Africa). The samples were tested using a 6.1 mm flat end stainless steel probe at a cross-head speed of 20 mm/min (Batu, 2004). The maximum force required to puncture the tomato skin was automatically recorded by the Bluhill® software. Mass loss was determined at selected storage intervals using the method proposed by Pinheiro, et al. (2013). Three batches of 3 tomatoes per treatment were marked and weighed on each sampling day. Subjective quality tests and marketability of fruit was
performed according to procedure followed by Tadesse, et al. (2012). Sampling was done over a 30-day storage period, on day 0, 8, 16, 24 and 30.

Data Analysis

Data analysis was carried out using SPSS 24 software (IBM statistics, USA). Multivariate analysis of variance (MANOVA) was used to analyse the effect of transportation conditions, storage conditions and pre-storage treatments on the quality of tomato fruit.

RESULTS AND DISCUSSION

Colour

The hue angle (h) of stored fruit across all treatments and storage conditions reduced with an increase in the storage duration. The h of tomatoes stored under cold storage conditions was higher than those stored under ambient conditions (Fig. 1). These trends are generally expected from a physiological and biochemical perspective. The h of tomato fruit generally reduces with ripening as fruit changes from green (h=180°) to red (h=0°).

The effect of pre-storage treatments on fruit colour change varied across the storage conditions. During the summer season, chlorine and biocontrol treatment appeared to be better in retarding colour changes of fruit harvested at green maturity stage. Fig. 1 presents a summary of the fruit h changes of tomatoes harvested in summer, subjected to various pre-storage treatments then stored in ambient and cold storage environments. Fruit stored under ambient storage conditions ripened faster than those stored in cold storage environment, and by the end of day 24, samples stored under ambient conditions had reached the end of their shelf-life. It appears from Fig. 1 that biocontrol treatment gave fruit with a higher mean hue angle compared to fruit subjected to other disinfection treatments, especially when treated fruit was stored in ambient storage environment.

A MANOVA of the data showed that disinfection treatments and supply routes had no significant (p>0.05) effect on the fruit h. On the other hand, the storage conditions had a significant (p≤0.05) effect on the h of fruit harvested.

Hurr, et al. (2005) reported that the storage environment had a significant effect on the changes in colour during storage of tomatoes after treatment with MCP-1, an observation that is in agreement with what was observed in this study. This study demonstrates that biocontrol treatment as a pre-storage treatment, can potentially produce fruit that has comparable colour to fruit treated with chlorinated water (Fig.1), a standard disinfectant in the tomato industry.

Figure 1: Effect of pre-storage treatments on the changes in fruit hue angle (h) for tomato fruit stored in Ambient (A) and cold (B) storage environments.
**Firmness**

Fruit firmness indicated as the maximum force required to puncture the flesh of tomato fruit varied with the storage environment and supply route conditions. The fruit firmness decreased across all the factors with storage duration. Fruit stored in cold storage environment, had higher firmness values compared to fruit stored under ambient conditions. Disinfection treatments had varied effects on fruit firmness. Fig. 2 depicts a summary of the effect of pre-storage treatments on the fruit firmness of tomatoes harvested in summer. Fruit stored under both ambient and cold storage environments showed good retention of firmness up to the eighth day. Better retention of firmness by fruit stored in cold storage environments than fruit stored in ambient conditions is expected as firmness changes in tomatoes is primarily an enzymatically controlled process that is also linked to other metabolic processes such as respiration. Higher temperatures generally speed up these processes.

Biocontrol treatment maintains a micro-coat on tomato fruit surface that not only competitively controls spoilage microorganisms, but also imparts barrier properties that results in a reduction in weight loss. The excellent maintenance of firmness by biocontrol treatment up to the eighth day relative to other treatments, may suggest that the loss in firmness could be mainly driven by respiration for the first eight days of storage. Lower firmness values later in the storage period could be due to access of the biocontrol yeast to internal nutrients of tomato fruit. This led to spoilage and decay leading to a pronounced drop in firmness. It was also noticeable during sampling that as the storage period increased, samples developed hard fruit skin, especially fruit that was subjected to hot water treatment.

Tomato fruit skin is made of an external epidermal layer and two to four layers of hypodermal cells (Hetzroni, et al., 2011). The morphology of the tomato skin affects its mechanical properties. It has been reported that the mechanical properties of tomato skin are primarily dependent on the cultivar (Hetzroni, et al., 2011). Heat treatments cause the production of COO- from pectin, which binds with Ca2+ ions forming salt-bridge cross-links (Mishra, 2002). This makes the cell walls increasingly inaccessible to enzymatic breakdown (Mishra, 2002).

![Figure 2](image-url)

**Figure 2:** Effect of pre-storage treatments on fruit firmness changes with storage duration during storage of tomato fruit stored in ambient (A) and cold (B) storage environments.
Biocontrol treatment appeared to give the best firmness in fruit stored in cold storage conditions as well as fruit of harvested at pink maturity stage, while chlorinated water was the best for fruit harvested at red maturity stage (data not shown). Based on MANOVA of the data, storage conditions and farms which fruit was sourced had a significant effect (p≤0.05) on the changes in tomato fruit firmness, while the pre-storage treatments had no significant (p>0.05) effect on the fruit firmness. Fruit transported through EM had a significantly (p≤0.05) higher firmness compared to fruit transported through ZZ and PD. However, Biocontrol treatment produced fruit with firmness values comparable to those treated with chlorinated water and was particularly good in maintaining the firmness of fruit harvested at the pink maturity stage and fruit stored under cold storage conditions.

**Mass loss**

The mass loss of fruit stored under ambient storage was higher than that of fruit stored under cold storage conditions. Fig. 3 depicts the effect of pre-storage treatments on the variation in fruit mass loss for tomatoes transported through the various supply routes and stored under ambient and cold storage conditions.

The pre-storage treatments had varied effects on the fruit mass loss, depending on the storage and supply route conditions. Biocontrol treatment had the relatively lower mass loss for the entire storage period for fruit harvested and transported through the supply routes and both storage conditions (Fig. 3). A MANOVA of the data showed that the storage conditions and farms where fruit was sourced had a significant (p≤0.05) effect on the mass loss of fruit harvested in the summer season. The pre-storage treatments were also not significant (p>0.05) factor on the fruit mass loss. Fruit transported through the PD route had significantly (p≤0.05) higher mass loss than fruit transported through EM and ZZ routes.

Mass loss in tomato fruit is primarily driven by transpiration (Tadesse and Abtew, 2015). It has been reported by Tadesse and Abtew (2015) that mass loss is dependent on the prevailing temperature conditions. The observations in this study are consistent with those cited in the literature, since the fruit mass loss depended mainly on the prevailing environmental conditions. Biocontrol treatment may have created a coating that created a micro-environment around the fruit surface that further reduced water loss. In this way, it managed mass loss better than the other pre-storage treatments especially for fruit stored under ambient conditions. Hot water treated fruit showed the least mass loss for fruit stored under cold storage conditions compared to fruit subjected to other pre-storage treatments.

![Figure 3](image-url)

**Figure 3**: Effect of pre-storage treatments on changes in cumulative mass loss with storage period for tomato fruit stored in ambient (A) and cold storage (B) conditions.
**Subjective quality**

Visual observations of incidences of decay, physiological disorders and disease incidences showed that mould attack was prevalent across all treatments towards the end of the storage period. Hot water treated samples depicted skin charring and the development of patched colouring. The control samples depicted more rotting compared to other pre-storage treatments. Chlorine treated samples had the least disease incidence compared to the other pre-storage treatments. Although biocontrol treatment was slightly better than the control in terms of disease incidence, biocontrol treated fruit showed the formation of white scum on their surface. Microbial analysis of this scum was not carried out, but it can be speculated that it is due to the effect and the growth of the B-13 yeast isolate on the skin surface of the fruit. These changes are depicted in Fig. 4.

A MANOVA of the data showed that the storage conditions, farms where fruit was sourced and the pre-storage treatments had a significant effect (p≤0.05) on the marketability of the fruit. The marketability of fruit treated with chlorine and biocontrol did not show any significant differences (p>0.05) in their marketability.

**CONCLUSION**

This study investigated the potential of a yeast isolate, B-13 as a pre-storage treatment that can be used in controlling the spoilage of tomato fruit in selected South African supply chains. Biocontrol treatment gave fruit quality comparable to that treated using chlorine in terms of fruit marketability and colour. It also gave relatively low weight loss compared to the other treatments. Although incidences of rotting were observed towards the end of the storage, it generally showed potential as a useful pre-storage treatment that can be improved through further research in its microbiological characteristics and integration with other pre-storage treatments.

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