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.

Biocontrol 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. Biocontrol 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 biocontrol 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 (11oC). These pre-storage treatments involved dipping the fruit in; hot water (42.5oC 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 2o 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 upto 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: 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:** 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.
**Figure 4**: A pictorial representation of common disease incidences and physiological disorders of tomato fruit. A is fruit treated using Biocontrol, B hot water, C control and D chlorinated water.

**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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