CoolBot Coldroom Technology Enhance Postharvest Quality and Shelf-life of Tomato (*Solanum lycopersicum* L.) Fruits

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Abstract

Fruit and vegetable value chain actors in developing countries experience postharvest losses of 20 – 50% depending on the crop and management practices. One of the reasons for such loss is mentioned to be lack of affordable technologies to enhance produce storability during handling after harvest. Temperature management serves as the number one practice for extending shelf life of fresh produce. CoolBot is a device coupled to room air conditioner capable of dropping the room temperature to as low as 2°C. Storage rooms installed with the technology seem suitable for handling fresh fruits and vegetables over an extended period. Despite the awareness creation upon the value chain actors, they are yet skeptical of these technologies' performance and cost-effectiveness during utilization. Therefore, this study was designed to evaluate the performance and cost-effectiveness of two CoolBot Cold-rooms (CB-CR) independently, one set at temperature of 13±1°C and the other at 16±1°C, respectively. Tomato fruits of the variety Assila harvested at three maturity stages were used during the evaluation. A 2x3 factorial experiment arranged in a Completely Randomized Design (CRD) with two factors; storage condition (CB-CR at 13±1°C and CB-CR at 16±1°C) and Maturity stage (mature-green, breaker and light red) were used. Following 42 days of storage at pre-defined storage conditions, results indicated no significant interaction of maturity stage and storage condition among variables. However, external fruit colour change in terms of Lightness (L), Chroma (C*), and Hue (H*), marketable fruits (%), soluble solid content (% Brix), titratable acidity (MeqL-1), weight loss (%) and firmness-compression (kg/mm2) varied with maturity stages. External fruit colour change from yellow yellow-green colour (L*C*h* = 57, 31.7, 110) to yellow yellow-red (L*h*C*= 39.7, 42.3, 43.0) was delayed more on mature green (MG) compared to other stages at both CB-CR (13±1°C and 16±1°C). Percentage marketable fruits was much higher on mature green fruits (84.83%), followed by Breakers (60.91%) and light red (48.58%). Based on electricity consumption, storage of tomato at CB-CR 16±1°C (160.2 KWh) was more beneficial than at CB-CR 13°C (272.7 KWh) due to less power consumption. It is therefore imperative to conclude that, more benefit can be realized when CB-CR storage is combined with the proper harvest maturity stage. Similarly, mapping of crop price change over season is required for proper storage timing using the technology throughout the year.*

Keywords: CoolBot cold room, Post-harvest storage technologies, Tomato maturity stages, Storage temperature.

Introduction

Fruits and vegetables are perishable but the percentage of their post-harvest losses are much higher in developing ranging from 20 to 50% than in developed countries from five (5) to 35% (Hailu and Derbew, 2015). Most developing countries including Tanzania, experience high post-harvest losses due to poor postharvest handling practices that are partly attributed to unavailability and high cost of the necessary infrastructures (MOA, 2019). Tomato is among fruit vegetable crops that suffer the highest postharvest losses during the peak production season. Such losses are associated with poor handling, inherent high temperature and low relative humidity to which the crop is exposed after harvest. Temperature management is considered as the major factor in maintaining quality and extending shelf life of fresh horticultural produce (Kader, 2002). Low temperatures reduce the rate of respiration and ethylene production, hence delay produce deterioration (Mutari and Debbie, 2011). Mechanical refrigeration has been used to provide optimal storage conditions for fresh produce. However, it is not economical and practically feasible among small-scale farmers in developing countries due to its high investment and running costs (Kader, 2004; Kitinoja and AlHassan, 2010; Kitinoja *et al.,* 2011; Singh *et al.,* 2017).

Cold storage facilities have been advocated to reduce postharvest losses and maintain the quality of fresh fruits and vegetables for small-scale farmers in Tanzania. Cold rooms have been established in export farms and airports in Tanzania to meet the quality and safety standards of the export commodities, including fresh fruits and vegetables. It is however established that; under optimally low storage temperature fruits and vegetables can be kept for an extended period with little change in quality. In addition to the reduced rate of respiration and ethylene production, optimal low storage temperature also reduces growth of latent infections on the produce (Din *et al.,* 2011). Availability and access to low-cost storage postharvest technologies have been improving among value-chain actors in developing countries but little is known about their cost-effectiveness and performance on key crops to enhance utilization. To improve postharvest handling and marketing of fresh fruits and vegetables, numerous market collection centres have been established at different places in the country. A few of the existing produce collection centres have cold rooms installed with mechanical cooling units to enhance storability and hence the marketing of fresh fruits and vegetables. Unfortunately, most of such cold rooms are not utilized due to high running costs.

Recently, a mini packing house with two cold storage rooms (CoolBot Cold-rooms) of 2.94 m x 2.35 m x 2.59 m each has been established at Sokoine University of Agriculture (SUA) to serve as a model for produce handling for small/ medium scale farmers. Each of the two cold rooms has the capacity of storing 144 stackable plastic crates of (H x L x W = 28.5 cm x 62 cm x 37 cm) with a carrying capacity of 300 tomato fruits/crate (≈28.5 kg/crate). CoolBot is an innovative device which when fitted to a digital air conditioner of specified brands can turn a well-insulated room into a walk-in produce cooler (Saran *et al.,* 2013; Majubwa *et al.,* 2019). CoolBot has three temperature sensors: the air conditioner's fins, the air conditioner's temperature sensor (heater) and the storage room. When coupled to an air conditioner, the device can trick and override the air conditioner in a well-insulated room and drop the air temperature to as low as 2°C depending on the pre-set temperature (Saran *et al.,* 2013; Rivard *et al.* 2016; Majubwa *et al.,* 2019). In Tanzania, the cost of such walk-in cooler with well-insulated walls fabricated from an old marine shipping container was estimated at 4,150 USD and may as well vary with the country (Majubwa *et al.,* 2019).

CoolBot cold room has been found effective for storage of several horticultural produces. In India for instance, CoolBot cooler at 12 – 15°C has been efficient in maintaining firmness, freshness, and marketability of tomato and okra over 21 days of storage (Huidrom *et al.,* 2016). In Ghana, CoolBot cold room has been found to be cost-effective compared to traditional storage shade during several months of onions storage (Saran *et al.,* 2012). CoolBot cold rooms are effective in retaining optimal temperatures but limited in maintaining an ideal range of relative humidity (RH) for storage of some fresh horticultural produce (Tolesa and Workneh, 2018). Adoption of this technology to Tanzania requires extensive research to validate its efficacy under local conditions. It has been established that overall effectiveness of any postharvest technology can vary with the crop, harvest maturity, season, storage duration, and region of application (Saran *et al.,* 2012). Nevertheless, there are limited studies on the performance of the model mini cold rooms, particularly on its ability to prolong shelf life and maintain the quality of key fresh fruits and vegetables and generate benefits for small-scale farmers and marketers selling the commodities in the local markets. This study establishes the comparative performance of the two CoolBot Cold-rooms (CB-CR at 13±1^{o}C and 16±1^{o}C) in terms of produce quality retention and cost-effectiveness for storage of tomato fruits harvested at mature green, breaker, and light-red maturity stages.

Materials and Methods

Plant materials and storage facility

Tomato fruits of the variety "Assila" were harvested on 21st Nov. 2019 from a leased farm at Mlali village, Mvomero district. The fruits were selectively harvested at three maturity stages (physiological maturity/mature green, breaker, and light red) (Table 1). Sorted fruits were packed into plastic crates, and transported to the mini packinghouse at Horticulture unit, Sokoine University of Agriculture (SUA), Morogoro for storage experiments. The cold rooms in the mini pack-house have two separate cold storage rooms with well-insulated walls. Each of the rooms is also fitted with a CoolBot coupled air conditioner (Fig. 1).

Experimental design

A 2x3 factorial experiment arranged in a Completely Randomized Design (CRD) with two factors, storage conditions (CB-CR at 13±1^{o}C and CB-CR at 16±1^{o}C) and maturity stage (mature-green, breaker and light-red) were used. A total of 900 (approx. 85.5 kg) uniform and undamaged fruits per maturity stage were stored in each of the storage conditions in three replications. Three hundred (300) fruits (28.5 kg) were used per replicate, out of which 30 fruits were numbered and used for tracking colour change at three days interval until the 42nd day

Table 1: Horticultural maturity indices for harvesting tomato fruits

S/N	Ripeness/harvesting stage	External color/appearance
1.	Mature green	Fruit surface is completely green; the shade of green may vary from light to dark.
2.	Breaker/turning	Breaker - There is a definite break in color from green to tannish-yellow, pink, or red on not more than 10% of the surface. Turning - 10 to 30% of the surface is not green; in the aggregate, shows a definite change from green to tannish-yellow, pink, red, or a combination thereof
3.	Light red	60 to 90% of the surface is not green; in the aggregate, shows pinkish-red or red.

Source: Sargent and Moretti (2016)

Figure 1: Wall insulation in a cold room (a) and a CoolBot mounted on an air conditioner in a cold room (b) at the Horticulture unit in SUA, Morogoro, Tanzania.
Source: Majubwa *et al.* (2019)

of storage. The percentage of marketable fruits and physiological weight loss per replicate was established at the 42nd day of storage when at least one treatment combination had 50% of the fruits unmarketable. At the 42nd day of storage, a total of 36 fruits were sampled per replicate for destructive measurements including firmness (puncture/compression force), soluble solid content (SSC), and titratable acidity (TA).

Data collection

Fruit weight loss

Fruit weight loss was measured according to Huidrom *et al.* (2016) using a digital kitchen scale (Ozeri, ZK 14-S) and percentage physiological weight loss (PWL) established as per equation 1.

$$PWL(\%) = \frac{Initial\ weight(g) - \text{Final weight(g)}}{Initial\ weight(g)} \times 100 \quad (1)$$

Fruit colour change

Fruit colour change was measured according to (Diaz-Mula *et al.,* 2012) using a Minolta Chroma meter (Chroma meter CR-400, Konica Minolta Inc., Japan) in the CIE colour space; Hue (h*), Chroma (C*), and Lightness (L*). Two measurements were taken per fruit one on each side along the fruit equator.

Fruit firmness

Fruit firmness in terms of compression and puncture force was measured using a hand-held pressure tester (FT 011, USA) mounted on a manual test stand (QA Supplies LLC, USA). The force (kg/mm2) required to compress the fruit to 10mm using a round-tip probe of 11 mm diameter was recorded. Similarly, the force required to puncture the puncture the fruit using a flat tip probe of 3.2 mm diameter was recorded. 2.3.4 Fruit soluble solid content and titratable acidity

Fruit SSC and TA were measured according to Huidrom et al. (2016). For SSC, 1ml of blended and well-filtered tomato fruit juice sample was added on a handheld digital refractometer (Antago PAL-1, Japan) and readings in percentage brix were recorded. The percent of dominant acid (citric acid) in tomato fruit was determined according to Rajwana et al. (2010) by pipetting 5ml of tomato juice into 50mls of distilled water and titrate against 0.1N NaOH to 8.2 pH using an automatic potentiometric titrator (HI 901, Hanna Instrument, USA). The percentage of dominant acid was then calculated based on equation 2.

$$Titratable\ acidity(\%) = \frac{0.1N\ NaOH\ used \times 0.064}{Volume\ of\ sample\ used} \times 100 \quad (2)$$

Where; N = normality

Percentage marketable fruits

Visual fruit quality assessment was done weekly, discarding fruits found with unacceptable market quality. The non-marketable fruits were sorted based on defects on fruit skin i.e., visible mould growth, decay, shriveling, smoothness, and loss of fruits' shininess rendering them unsuitable for the local market. Finally, the percentage of marketable fruits was calculated based on equation 3.

$$Marketable\ fruits(\%) = \frac{Number\ of\ marketable\ fruits}{Total\ number\ of\ sampled\ fruits} \times 100 \quad (3)$$

Rate of electricity consumption per storage condition

The average amount of electricity (KWh/day) used in each CB-CR unit (13±1°C and 16±1°C) was recorded daily using a single-phase electric meter (DDS28II, Eurotrix, PRC) throughout the storage period to establish the rate of power consumption for the storage technology.

Data Analysis

The data was subjected to the analysis of variance (ANOVA) using Genstat statistical software (Version 16, VSN International, UK). Prior ANOVA, the collected and processed data were subjected to normality test using Shapiro-Wilk Test, no further transformation was executed as the data was found to be normally distributed. Mean separation was based on Tukey HSD at p = 0.05. Since it was a 2x3 factorial experiment with storage condition (A) and fruit harvesting stage (B) at two (i2) and three (j3) levels, respectively, the ANOVA model for this experiment was:

$$Y_{ijk} = \mu + \tau_i + \delta_j + (\tau\delta)_{ij} + \epsilon_{ijk} \quad (4)$$

where:

μ represents the overall mean effect

τi is the effect of the ith level of factor A (i = 1, ith)

δ_j is the effect of the jth level of factor B (j = 1, 2, jth)

$(\tau\delta)_{ij}$ represents the interaction effect between A and B

ϵ_{ijk} represents the random error terms (which are assumed to be normally distributed with a mean of zero and variance of σ2) and the subscript k denotes the m replicates (k = 1, 2, m)

Results

Fruit external colour change

In tomato, colour change from green to red colour indicated by the decrease in Hue angle (H*) and Lightness (L*) and increase in Chroma (C*) values serves as the major index of harvest maturity, ripening and/or senescence during storage. This study tracked the colour change of mature green, breaker, and light-red tomato fruits during the 42 days of storage in CB-CR at 13±1°C and 16±1°C conditions. The results (Fig. 2) indicated a significant (p<0.001) delay in decrease of H*, L* and increase of C* values among fruit maturity stages over storage time at both storage conditions post harvesting time of tomato fruits stored in CB-CR at 13±1°C and 16±1°C. Colour change was delayed on mature green compared to other stages in both CB-CR (at 13±1°C and 16±1°C) from yellow yellow-green (L*C*h*=57, 31.7, 110) to yellow yellow-red (L*h*C*= 39.7, 42.3, 43.0).

Percentage weight loss

Regardless of the storage conditions, percentage physiological weight loss of the stored tomato fruits differed significantly (p<0.001) among maturity stages during the 42 days of storage in CoolBot Cold-rooms (Fig. 3). At both storage conditions, tomato

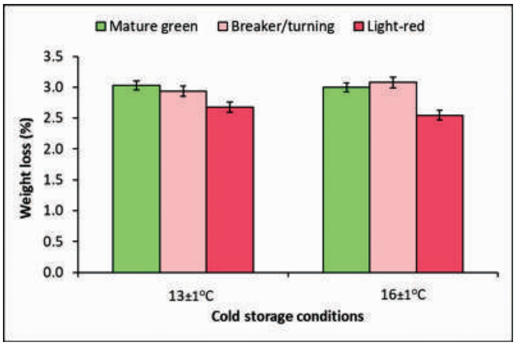

Figure 3: Effect of maturity stage and storage conditions on physiological weight loss of tomato fruits following 42 days of storage in CoolBot Cold-rooms at 13±1°C and 16±1°C conditions

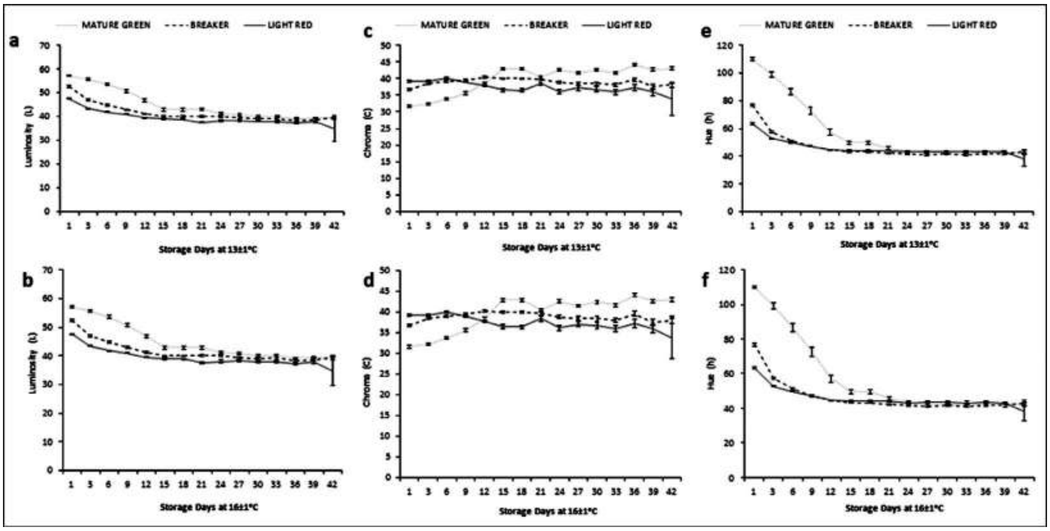

Figure 2: Trend of change in colour lightness (L*) (a & b), colour intensity (C*) (c & d) and, actual colour (h*) (e & f) respectively on mature green, breaker, and light-red tomato during the 42 days storage in CB-CR at 13±1°C and 16±1°C, respectively.

fruits at light-red maturity stage experienced the lowest physiological weight loss (2.6%) than those at mature green and breaker stages (3%). However, the percentage weight loss did not differ significantly among the two storage conditions (p=0.90), as well as the interaction (p=0.188) between the storage conditions and fruit maturity stages.

Fruit firmness

The force required to compress and puncture the stored fruits differed significantly (p<0.001) among maturity stages during the 42 days of storage in CoolBot Cold-rooms regardless of the storage conditions (Fig. 4a,b). The lowest compression and puncture force was recorded on breaker (1.94 kg/cm^2, 1.51 Kg/cm^2) and light-red (1.95 kg/cm^2, 1.33 kg/cm^2) than those stored on mature green (2.2 kg/cm^2, 1.7 kg/cm^2). However, the force required to compress and puncture the fruits did not differ significantly among the two storage conditions (p=0.128, p=0.934), as well as the interaction (p=0.539, p=0.553) between the storage conditions and maturity stages.

Soluble solid content (SSC) and Titratable acidity (TA)

Soluble Solid Content and TA varied significantly (p<0.001) with fruit maturity stages despite the storage condition whereby, mature green fruits had higher SSC (3.91%) and TA (4.68 MeqL-1) than breaker (3.57%, 3.34 MeqL-1) and light-red (3.58%, 3.12 MeqL-1) fruits (Fig. 5a,b). However, both storage condition and the interaction between the storage conditions and maturity stages showed no significant effect on SSC (p=0.463, p=0.373) and TA (p=0.364, p=0.224).

Percentage marketable fruits

Following 42 days storage of tomato fruits

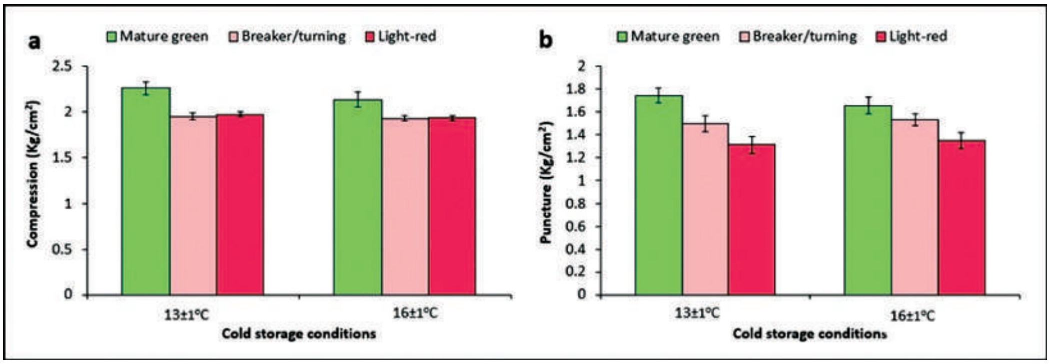

Figure 4: Effect of maturity stage and storage condition on fruit firmness (kg/cm^2); (a) compression and (b) puncture force following 42 days of storage in CoolBot Cold-rooms at 13±1°C and 16±1°C conditions

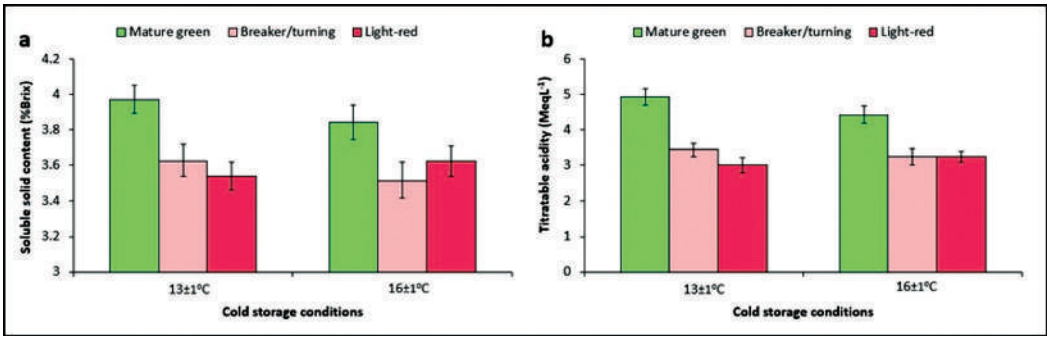

Figure 5: Effect of maturity stage and storage conditions on (a) soluble solid content and (b) titratable acidity of tomato fruits following 42 days of storage in CoolBot Cold-rooms at 13±1°C and 16±1°C conditions

in CB-CR 13±1°C and 16±1°C, overall results (Fig. 6) indicated significantly ($p<0.001$) higher percentage of marketable fruits on mature green fruits stored in CB-CR at 13±1°C (87%) and CB-CR at 16±1°C (83%) than on other maturity stages across storage conditions. The lowest percentage of marketable fruits was found on light-red fruits stored in CB-CR at 13±1°C (47.1%) and CB-CR at 16±1°C (50.1%). Comparative effectiveness of the storage conditions with respect to fruits harvesting stages indicated that, storage of mature green and breaker fruits in CB-CR at 13±1°C can give 4% and 2% more marketable fruits, respectively than in CB-CR at 16±1°C, while storage of light-red in CB-CR at 16±1°C can give 3% more than those stored in CB-CR at 13±1°C.

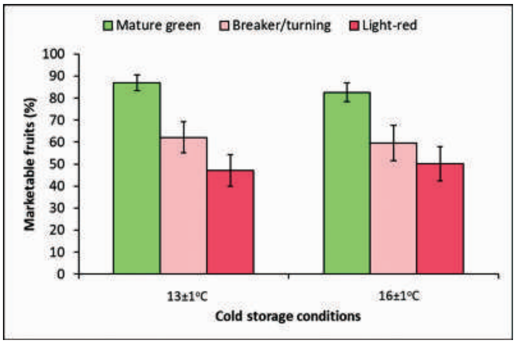

Figure 6: Effect of maturity stage and storage conditions on fruit marketability following 42 days of storage in CoolBot Cold-rooms at 13±1°C and 16±1°C conditions

Rate of electricity consumption per storage condition

The results (Fig. 7) revealed that, the average amount of electricity consumed during the six weeks (42 days) of storage differed significantly ($p<0.001$) among the two CoolBot Cold-room storage conditions. Generally, the comparative effectiveness of the storage conditions indicated that, with an average consumption of 5.986 KWh/day (251.4 KWh/42 days), storage in CB-CR at 13±1°C consumed more electricity than storage in CB-CR at 16±1°C which used 4.879 KWh/day (204.9 KWh/42 days). Storage in CB-CR at 13±1°C consumed 46.5 KWh more than CB-CR at 16±1°C for the 42 days of storage.

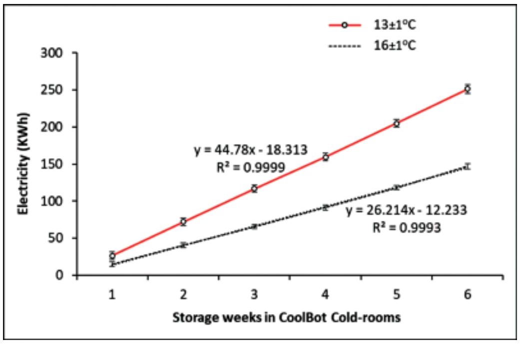

Figure 7: Rate of electricity consumption associated with storage of tomato fruits in CoolBot Cold-rooms at 13±1°C and 16±1°C conditions for 42 days

Discussion

Storage of mature green tomato fruits in CB-CR at13±1°C and 16±1°C conditions was much effective in delaying fruit colour change during the 42 days of storage. The observed delay in colour change as indicated by higher H* and lower C* values on mature green compared to breaker and light-red stored in CB-CR at 13±1°C and 16±1°C was consistent with previous studies (Getinet *et al.,* 2008; Pinheiro *et al.,* 2013). Like our findings, Roberts *et al.* (2002) also reported faster colour change on tomato fruits stored at 20°C than at 12°C. High rate of colour change indicates how fast tomato fruit ripens and or senescence (Baldwin *et al.,* 2011) and it is a function of maturity stage, variety, and storage environment including temperature (Getinet *et al.,* 2008; Tigist *et al.,* 2013; Arah *et al.,* 2015). High storage temperatures increase respiration rate and accelerates ethylene production that hastened ripening (Mutari and Debbie, 2011). However, early maturity stages; mature green and breaker tend to have lower ethylene production and respiration rates at early days of storage than pink and red-ripe fruits (Tilahun *et al.,* 2019).

Physiological weight loss is the major cause of produce shriveling and loss in freshness, on the other hand fruit firmness is also a physical indicator of fruit loss in freshness. Firm, turgid, uniform, and shiny color appearance as well as absence of signs of mechanical injury, shriveling, or decay indicate high-quality tomato fruits (Sargent and Moretti, 2016). The lower physiological weight loss and firmness of tomato fruits stored in CB-CR at 13±1°C and 16±1°C observed in this study during the 42 days of storage could be attributed to low storage temperature. Physiologically fresh produce tends to have higher water content than shriveled ones and hence are more turgid and prone to transpiration. Low storage temperature reduces vapour pressure difference between fruits and surroundings (Getinet *et al.,* 2008). Such differences in vapour pressure tend to minimize the rate of moisture removal from tomato fruits to surroundings and reduces/slower the deterioration (Seyoum and Woldetsadik, 2004). In the present study, firmness measured in terms of resistance to compression and puncture force was higher on mature green fruits when stored in CB-CR at 13±1°C and 16±1°C than on other maturity stages under same storage conditions during the 42 days of storage. The relatively lower storage temperature observed in CB-CR at 13±1°C and 16±1°C storage conditions may have a significant contribution in decelerating cell break down due to respiration. Fruit softening has been attributed to either loss of cell turgidity caused by water loss and or cell wall breakdown due to respiratory processes (Mutari and Debbie, 2011). Similarly, the lower physiological weight loss experienced in CB-CR at 13±1°C and 16±1°C storage conditions likely accounts for enhanced firmness of the stored tomato fruits.

In the present study, the interaction between fruit maturity stage and storage condition did not have significant effect on amount of SSC and TA. Both SSC and TA served as indicators of change in internal fruit quality during maturity and storage. The higher SSC and TA on mature green fruits stored in CB-CR at 13±1°C and 16±1°C than on light-red and breaker fruits, respectively indicated an interactive effect of storage condition (temperature) and maturity stage. These results were consistent with Baldwin *et al.* (2011) who reported higher TA on mature green tomatoes of variety Florida 47 stored at 13°C. Similarly, Tilahun *et al.* (2019) reported relatively high TA on breaker compared to pink and red tomato of cultivar TY Megaton on 12 days of storage. Previous study by Teka (2013) reported a decline in TA through advancement of maturity stage with the highest on mature green fruits. Similar to our findings, Tilahun *et al.* (2019) also reported no significant difference in SSC between breaker, pink and red maturity stages of tomato cultivar TY Megaton stored at 12°C. Optimal storage temperatures depend on the maturity stage of the tomatoes, whereby the ideal conditions for ripening are 19 to 21°C with 90 to 95% RH (Sargent and Moretti, 2016). Storage of tomatoes at temperatures >27°C reduces intensity of red color, while storage at <13°C slows ripening and result to development of chilling injury, especially in tomatoes stored at the mature-green stage. Red tomatoes can be stored at 7°C for several days, though tomatoes stored at 10°C turn out to have low in flavor and aroma than those held at 13°C (Sargent and Moretti, 2016).

Overall performance of the tested storage technologies indicated higher percentage of marketable fruits when fruits harvested at mature green stage and stored in CB-CR at 13±1°C or 16±1°C than other maturity stages under same storage conditions. The observed high percentage of marketable mature green tomato fruits in CB-CR at 13±1°C and 16±1°C could be associated with low physiological weight loss accounted by low storage temperatures. Similarly, Huidrom *et al.* (2016) reported significant retention of higher marketable Chilli, torai, brinjal, okra and tomato fruits following 21 days of storage in cold room at 12-15°C compared to those stored at ambient. In respect to maturity stage, Getinet *et al.* (2008) found higher percentage of marketable fruits among mature green tomato stored under cold storage than turning and light-red fruits at same or ambient storage conditions. Higher storage temperature increase rate of transpiration, respiration and ethylene production and hence hasten senescence (Mutari and Debbie, 2011). Harvesting at an improper maturity stage hastens postharvest losses in fresh produces including tomato (Sargent and Moretti, 2016).

Pertaining electricity consumption rate, storage of tomato in CB-CR at 16±1°C was more beneficial than in CB-CR at 13±1°C due to less power consumption. However, more benefit can be realized when CB-CR storage is combined with proper harvest maturity stage.

It is well established that, energy consumption rate of refrigeration unit tends to increase with condition, type, and quantity of the stored produce (Adre and Hellickson, 1989). The speculated benefit of the CB-CR technology may also vary up or down stream among seasons in a year with increase or decrease in rate of produce price change. Therefore, it should be noted that any change on these factors could alter the benefit gained out of the CB-CR technology. Storage of fresh tomato fruits may be financially feasible if the cost of storage (including electricity consumption) is less than the increased value of the stored produces when sold during the off-season (PI LLC, 2017). The approach of using a room AC and CoolBot device effectively minimizes on-farm electricity use compared to a conventional refrigeration system, therefore saving not only the installation and repair costs but also helps to save electricity.

Conclusion and recommendations

The study evaluated comparative performance on tomato quality retention and electricity consumption effectiveness of CoolBot Cold-rooms (CB-CR) at 13±1°C and 16±1°C conditions. Tomato fruits of variety "Assila" as a model crop at mature green, breaker and light-red maturity stage were stored for 42 days in each storage condition. Based on the results, it could be concluded that; despite the higher performance of CB-CR 13±1°C than CB-CR at 16±1°C, the two storage conditions were effective in reducing fruit physiological weight loss, delaying fruit colour change, maintaining fruit firmness, TA, SSC, and higher percentage of marketable fruits particularly when fruits were harvested at mature green stage. Storage of tomato in CB-CR at 16±1°C was more beneficial than in CB-CR at 13±1°C in terms of less power consumption. Nevertheless, more benefit can be realized when CB-CR storage is combined with proper harvest maturity stage. Further studies are suggested to evaluate performance and cost effectiveness of the technology for high value horticultural crops particularly fruits and vegetables with export potential such as snap beans, broccoli, and cauliflowers. Studies are also required to map the demand, supply, and price changes across seasons for high value horticultural crops to enhance utilization of the technology.

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