Efficacy of storage treatments in delaying ripening in Avocados and reduce postharvest losses

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Abstract

The present study investigated the ripening and senescence time, and the spoilage of avocados after ripening. Storage treatments used in the study included the open air, perforated and closed plastic sachets, Zero Energy Cooling Chamber (ZECC), and cold room. Avocados were harvested and brought to Postharvest Training Center at Mulindi, Rwanda. Nine (9) mature green avocados (Hass variety) without defects were selected for each treatment. The pulp temperature (ºC) and RH (%) of the storage package were recorded three times daily - morning (8:00), noon (12:00) and evening (16:00). Respective days to ripening and to senescence after ripening of avocados were - 11 and 5 in the open air, 8 and 8 in a perforated sachet, 9 and 7 in ZECC, and 22 and 8 in a cold room. The amount considered as a loss after ripening were - 56% in the open air, 33% in a perforated sachet, 22% in ZECC, and 11% in cold room. All Avocados in closed plastic sachets were rotted and were not attractive for consumption. Overall results showed that conservation of avocados in cold places with higher RH and ventilation can prolong their postharvest shelf life by delaying their ripening time and thus significantly reducing their postharvest losses.

Keywords: *Relative humidity, Ripening, Pulp temperature, weight, firmness, Avocado loss*

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Introduction

The postharvest shelf life of avocados can be significantly affected by temperature and relative humidity (RH) of the place in which they are kept. For good eating quality, avocados should contain more than 10 % oil. The oils in the avocado are mainly polyunsaturated oils and contain no cholesterol. The oil content in the avocado mesocarp is indicative of maturity and fruit quality, which is related to the firmness of the fruit, where avocados with a high oil content, i.e. picked towards the end of a cultivar's season softens faster than early fruit with low oil content (Galvão et al., 2014).

The storage of perishable commodities such as avocados is a critical aspect of the post-harvest supply chain, influencing their quality, shelf life, and marketability. As global demand for avocados continues to rise, there is a growing need for effective storage solutions to mitigate post-harvest losses and ensure a consistent supply of high-quality produce (Lourentzatos, 2021). Avocado, is renowned for its nutritional value and versatile culinary applications. However, its susceptibility to physiological and microbial deterioration as other horticultural produce necessitates careful storage management (Nazir et al., 2024). Avocados require high relative humidity condition during storage (Hofman, et al. 2002a; Getinet, 2011). The avocados in the study were kept in open air, stored in perforated and closed plastic sachets, Zero Energy Cooling Chamber (ZECC) and cold room.

The open air storage method involves exposing avocados to ambient conditions, allowing natural air circulation. While cost-effective, this approach is influenced by external factors such as temperature, humidity, and pests, which may compromise the fruit quality. Open air storage is best suited for short-term preservation, on-farm storage, requiring complementary treatments for extended shelf life (Lal Basediya, 2013). Perforated and closed plastic sachets present an alternative strategy, creating a controlled microenvironment around the avocados. The permeability of the plastic regulates gas exchange, influencing factors like ethylene concentration and respiration rate. Studies by Oluwafemi (2011) have demonstrated the efficacy of modified atmosphere packaging in extending the shelf life of avocados by mitigating physiological changes associated with ripening. The Zero Energy Cooling Chamber (ZECC) represents a sustainable and energy-efficient solution for avocado storage. By utilizing natural convection and thermal mass, ZECC maintains a stable temperature, inhibiting enzymatic and microbial activities. Research by Lal Basediya et al. (2013) highlights the success of ZECC in preserving avocado quality while minimizing energy consumption, making it a promising technology for small-scale farmers and resource-limited regions. Cold rooms, equipped with controlled temperature and humidity settings, have long been a standard for post-harvest storage. The cold storage approach inhibits microbial growth, slows down respiration, and delays ripening processes (Wang and Wang, 2009). The pivotal role of cold rooms is in maintaining avocado quality throughout the supply chain, reducing spoilage and enhancing market competitiveness.

As the global avocado industry continues to evolve, the choice of storage treatment becomes pivotal in ensuring a sustainable supply of high-quality produce. By examining the advantages and limitations of open air storage, perforated and closed plastic sachets, ZECC, and cold rooms, the present work aimed at contributing to the optimization of post-harvest practices, thereby supporting the sustainable availability of raw fresh avocados.

Materials and Methods

Collection of samples

Avocado fruits (Hass var.) were harvested in agricultural season A from a farm in Bugesera district and brought in plastic crates in a vehicle to the Postharvest Training Center at Mulindi, Rwanda, which is situated at 45 km from the harvest farm. During transport, the avocados were covered with a perforated white sheet to protect them from direct sunlight.

Storage treatments

The different storage treatments used in the study were open air, perforated and closed biodegradable plastic sachets, Zero Energy Cooling Chamber (ZECC), and cold room. ZECC was a double brick-wall structure; the cavity was filled with sand and walls of the chamber were being soaked in water. At the same day of harvest, nine mature green avocados without defects (including avocados at breaking and ripening stages) were selected for each treatment and stored until they get overripe (Not attractive to sell or eat).

Measurements during the avocado storage

Temperature (^{o}C) and relative humidity (%) of avocados were recorded three times every day - morning (8:00), noon (12:00), and evening (16:00), using HOBO, Pro V2 (Electronic devices that records measurements, such as temperature or relative humidity, at set intervals over a period of time). Weight of avocados were recorded three times every day - morning (8:00), noon (12:00), evening (16:00), using digital scale (Pronto, Max.5 kg, China). Firmness (Kgf) was determined at breaking (if avocado is not too hard), ripening stage and overripening stages using penetrometer (model FT 0111; 0-11lbs). The outercoat of avocado was being removed before using penetrometer. Data were collected at three-day intervals and the firmness was measured from three position of the avocado fruit (anterior, middle and near to the basal part) without removing the seed. Rotten, bad looking avocados and not attractive to sell and eat were visually sorted out and were considered as a loss.

Statistical analysis

Data collected were subjected to one-way analysis of Variance (ANOVA) using SPSS (Statistical Package for Social Sciences) software version 20. Data for each treatment were collected in triplicate. Differences between the treatment means were identified using the Tukey's Test and the significance was accepted at $p < 0.05$.

Results and discussion

The pulp temperature (°C) and relative humidity-RH (%) of avocados were recorded three times every day - morning (8:00), noon (12:00), evening (16:00). The pulp temperature and RH were significantly different ($p< 0.05$) among all storages (Table 1). The results showed that the higher pulp temperature and the lower RH, the higher weight loss, except for avocados stored in cold room (Table 1).

Table 1. ***Effect of pulp temperature and relative humidity on weight of stored avocados***

Storage treatment	Pulp temperature (°C)			Relative humidity (%)			Weight loss (%)
	Average	Highest	Lowest	Average	Highest	Lowest	
Open air	27.4^{a}			61.4^{e}		54.1	84.4^{a}
Perforated plastic sachet	26.8^{b}			70^{d}			75.2^{b}
Closed plastic sachet	26.3^{c}	29.4		73.5_{c}			18.8^{e}
ZECC	21.9^{d}			79.8^{b}			69.1^{c}
Cold room	11.5^{e}		7.7	83.1^{a}	87.6		53.74^{d}

Values are means of 3 replications. Means followed by different letters in the same column are significantly different at P < 0.05.

Air conditioner in cold room which speeded up the movement of air caused the avocados to lose weight more than the avocados stored in ZECC did. It was revealed that by increasing the relative humidity, the vapour pressure deficit if reduced, results in less water loss (Blakey, 2011). The ZECC lowered the temperature and maintained high humidity inside the chamber. The water contained in the sand between the two brick walls evaporated towards the outer surface of the outer wall, where the drier outside air was circulating. The evaporation process automatically caused a drop in temperature of several degrees from ambient temperature, cooled the inner container and preserved the avocado inside. Kumar (1993) reported that ZECC can reduce ambient temperature by 10-15°C and maintain high humidity of about 95% that can increase shelf life and retain quality of horticultural produce. The lowest weight loss (18.8%) was found in avocadoes stored in closed plastic sachets, while the ones kept in open air lost the highest weight

(84.4%) because the evaporation was faster in open air than in closed sachet. The negative effect of relative humidity on avocado texture and appearance could be attributed to water loss (Paull 1999). Perez (2004) reported that storage conditions of mature avocados at 5°C and a relative humidity of 85-90% could result in a shelf life of two-three weeks.

Table 2. ***Effect of storages on avocado softening***

Storage treatment	Breaking stage		Ripening stage		Over ripening stage	
	Time (day)	Firmness (Kgf)	Time (day)	Firmness (kgf)	Time (day)	Firmness(Kgf)
Open air	8	4.4[a]	11	2.5[a]	16	1.5[a]
Perforated plastic sachet	6	4.2[a]	8	2.4[a]	16	1.4[a]
Closed plastic sachet	nd	nd	nd	nd	nd	nd
ZECC	6	4.1[a]	9	2.4[a]	16	1.6[ab]
Cold room	18	4.1[a]	22	2.3[a]	30	1.6[ab]

Values are means of 3 replications (time excluded). Means followed by different letters in the same column are significantly different at $p < 0.05$. ***nd:*** *Not Detected*

Avocados reached breaking stage when they were softening with few days to ripe (Table 2); ripening stage when they were ready to eat and sell; and at over ripening stage when rotting, very bad appearance externally and internally.

Apart from avocados in perforated plastic sachet and ZECC which got at breaking stage on the same day (6th day), other avocados underwent breaking and ripening stages on different days in all storages (Table 2). However, avocados were overripened on the same day (16th day), except avocados in cold room which got over ripened on 30th day (Table 2). The low average pulp temperature and high RH in cold room (Table 1) influenced the avocados to take longer to break, ripen and overripen than avocados kept in open air, stored in perforated plastic sachet and ZECC (Table 2). Low temperature storage is the most commonly used method of extending storage life in the avocado. The extent to which the avocado can be chilled depends on the cultivar, temperature of storage, and period of storage (Munhuweyi et al., 2020). Avocados in perforated biodegradable plastic sachet showed a short time to ripen (Table 2) compared to avocados in other storage types. Avocados kept in closed sachet did not soften and ripen most likely because of a buildup of carbon dioxide in the closed unit, instead, they rotted.

Firmness can be described as the resistance to penetration determined by employing invasive, such as hand tactile methods, and destructive methods (Mizrach, 1999). Firmness is an indicator of softening or ripening of many fruits and vegetables. Hence the difference in decrease of firmness of avocado fruits in the different storages could be explained by difference in rate of respiration and temperature that affect the firmness of fruits (Lazan, 1995). Generally, as the storage time progressed, the firmness of avocados was reducing in all storages (Table 2). This decrease in firmness could be associated with three processes: The first is the breakdown of starch to soluble sugar (Irtwange, 2006). The second is the breakdown of cell wall or reduction in the middle lamella cohesion due to solubilization of pectin substances (Irtwange, 2006). The third is the movement of water from the peel to the pulp during ripening due to the process of osmosis (Dadzie, 1997). Avocados in open air, in perforated biodegradable plastic sachet, in ZECC and in cold room did not show significant difference ($p < 0.05$) in firmness at breaking, ripening and over ripening stages (Table 2).

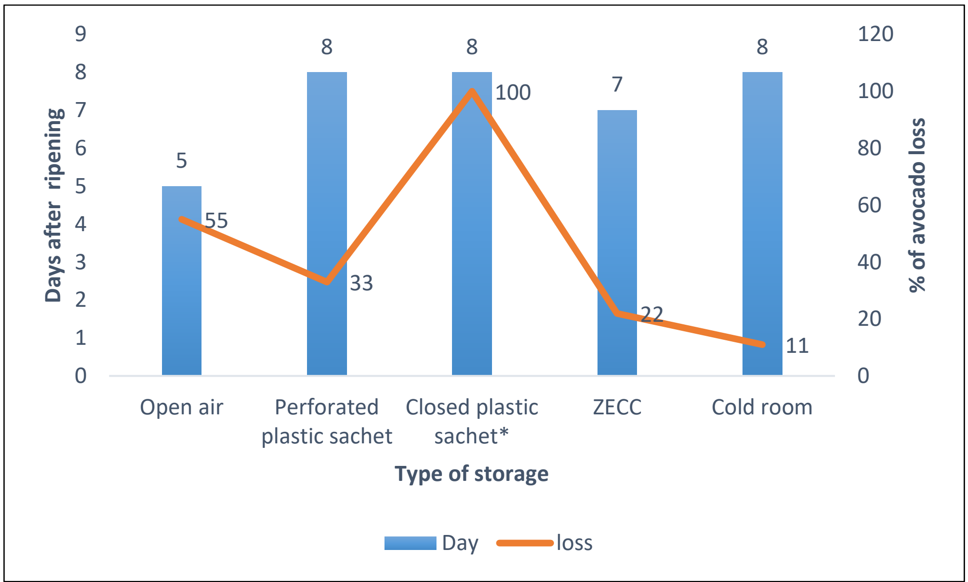

Figure 1. Percentage of avocado loss after ripening stage
**Avocados in closed plastic sachets did not ripen*

In the present work, rotten, bad looking avocados and not attractive to sell and eat were visually sorted out and considered as loss. In Figure 1, 55.5 % (5 out of 9), 33.3 % (3 out of 9), 22% (2 out of 9) and 11.3% (1 out of 9) avocados were considered as a loss at day 5, 8,7, and 8 after ripening time in open air, perforated plastic sachet, ZECC and cold room, respectively. Softening avocados kept in open air underwent early and high loss because they were highly exposed to the attack of insects and other external damaging agents compared to avocados stored in perforated plastic sachet, ZECC and cold room. Thus, avocados should be stored in a protected environment.

Perforated packages protected avocados from external damaging substances such as pests, rodents and dust. Provision of ventilation into avocados reduced risks of damage from a build-up of carbon dioxide and ethylene gases. As it can be observed, 100% (9 out of 9) avocados in closed plastic sachet all rotted and were lost without going through breaking and ripening stages (Figure 1) most likely because of their average pulp temperature was as high as 26.3°C (Table 1) with unbalanced buildup of carbon dioxide, oxygen and ethylene in the closed unit. It was found that the use of storage conditions containing high concentrations of carbon dioxide and low concentrations of oxygen coupled with low temperatures proved successful in delaying ripening and senescence in avocados (Bereda, 2016). In other works, low levels of oxygen decreased overall respiration rate, and also appeared to block the ethylene-forming system (Affandi et al., 2021). High carbon dioxide concentrations reduced ripening of avocados, possibly by acting as a competitive inhibitor of ethylene (Krupa and Tomala, 2021).

As the temperature in ZECC was lower than the ambient temperature, ripening of avocados in ZECC could be a way to reduce possible damages that can happen to this commodity from high ambient temperature. The storage of avocados in ZECC as a low-cost facility, improved their shelf-life by limiting the transpiration and respiration (Dhemre, 2003).

Conclusion

Post harvest losses in fresh avocados may occur anywhere from the point where fruits have been harvested up to the points of consumption. Avocados are naturally delicate; they are target to many postharvest injuries and mechanical damages due to their thin skin and climacteric type of ripening nature. Avocados have limited shelf life of less than a week under ambient conditions. Hence, efficient storages which minimize mechanical damage, contamination, moisture loss, slow down respiration rate, low temperature and inhibit the developments of decay causing pathogens are needed for better protection and shelf-life improvements of the avocados.

In this study, avocados in closed plastic sachet all rotted and were considered as loss. Softening avocados kept in open air underwent early and high loss because they were highly exposed to the attack of insects and other damaging agents compared to avocados stored in perforated plastic sachet, ZECC and cold room. High amounts of avocados considered as a loss (rotten, leading not to sell or eat) after ripening (at Overripening or senescence stage) was found in avocados kept in open air. Low loss was for the avocados stored in cold room, followed by avocados in ZECC. Overall results showed that cold places with higher RH and ventilation can prolong the postharvest shelf life of avocados by delaying ripening time and thus significantly reducing their postharvest losses.

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Conflict of interest

Authors declare no conflict of interest

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