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Research Application Summary

Effectiveness of cold chain management practices on shelf life of mango fruit

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Abstract

Mango is a highly perishable fruit with a shorter shelf-life if not well preserved immediately after harvest. Maintaining a proper cold chain management from the time of harvest till the fruit reaches the consumer is key in preservation of quality for harvested fruits and vegetables. However, the use of proper cold chain management is always avoided by players in the mango value chain because of its perceived complexity and other logistical challenges. Creating awareness by training and demonstrating using simple good practices and low cost technologies (proper harvesting time, precooling and cold storage of harvested fruits) will be of need to help change the mindset on use of cold chain management to reduce post-harvest losses in mangoes. A study was set to evaluate the effect of proper cold chain management on preservation of postharvest quality of harvested mangoes. Homogeneous mature green 'Kent' mangoes were harvested in the morning and at midday. Fruits harvested in the morning were stored under ambient conditions and in the Coolbot™ cold room. For fruits harvested at midday, one batch was precooled in the evaporative charcoal cooler until temperatures stabilized at 22.5°C stored in the Coolbot™ cold room while the other batch was stored under ambient conditions without precooling. Changes in pulp temperature, physiological weight loss, colour, firmness and total soluble solids were determined throughout the storage. Results showed that fruits under ambient conditions had cumulative weight loss of 13.3% and 12.6% for fruits harvested in the morning and midday respectively. Those in the Coolbot™ cold room, cumulatively lost 10.5% and 9.7% of weight for fruits harvested in the morning and midday respectively on their final day. There was a significant difference in fruit colour, firmness and total soluble solids for fruits in the Coolbot™ cold room as compared to fruits stored in ambient conditions but the difference in harvesting time was not significant. Fruits harvested at midday and stored in ambient conditions had the shortest shelf life of 13 days while all fruits in the Coolbot™ cold room had a longer shelf life of 32 days. Harvesting fruits in the morning or precooling in the charcoal cooler followed by storage in Coolbot™ cold room extended shelf life of harvested mangoes. Proper cold chain management can be adopted by farmers doing fruit aggregation to attain right tonnage for buyers and later processing.

Keywords: Coolbot, evaporative cooler, low temperatures, postharvest, precooling

Résumé

La mangue est un fruit hautement périssable avec une durée de conservation plus courte s'il n'est pas bien conservé immédiatement après la récolte. Le maintien d'une bonne gestion de la chaîne du froid à partir du moment de la récolte jusqu'à ce que le fruit atteigne le consommateur est essentiel pour préserver la qualité des fruits et légumes récoltés. Cependant, l'utilisation d'une bonne gestion de la chaîne du froid est toujours évitée par les acteurs de la chaîne de valeur de la mangue en raison de sa complexité perçue et d'autres défis logistiques. La sensibilisation par la formation et la démonstration de l'utilisation de bonnes pratiques simples et de technologies à faible coût (temps de récolte approprié, pré-refroidissement et stockage au froid des fruits récoltés) sera nécessaire pour aider à changer l'état d'esprit sur l'utilisation de la gestion de la chaîne du froid pour réduire les pertes post-récolte dans les mangues . Une étude a été mise en place pour évaluer l'effet d'une bonne gestion de la chaîne du froid sur la préservation de la qualité post-récolte des mangues récoltées. Des mangues vertes homogènes matures «Kent» ont été récoltées le matin et à midi. Les fruits récoltés le matin ont été stockés dans des conditions ambiantes et dans la chambre froide CoolbotTM. Pour les fruits récoltés à midi, un lot a été pré-refroidi dans le refroidisseur à charbon évaporatif jusqu'à ce que les températures se soient stabilisées à 22,5 ° C stockées dans la chambre froide CoolbotTM tandis que l'autre lot a été stocké dans des conditions ambiantes sans pré-refroidissement. Les changements de température de la pulpe, de perte de poids physiologique, de couleur, de fermeté et de solides solubles totaux ont été déterminés tout au long du stockage. Les résultats ont montré que les fruits dans des conditions ambiantes avaient une perte de poids cumulée de 13,3% et 12,6% pour les fruits récoltés respectivement le matin et le midi. Ceux de la chambre froide CoolbotTM ont perdu cumulativement 10,5% et 9,7% de poids pour les fruits récoltés respectivement le matin et le midi lors de leur dernier jour. Il y avait une différence significative dans la couleur, la fermeté et la teneur totale en solides solubles des fruits dans la chambre froide CoolbotTM par rapport aux fruits stockés dans des conditions ambiantes, mais la différence de temps de récolte n'était pas significative. Les fruits récoltés à midi et stockés dans des conditions ambiantes avaient la durée de conservation la plus courte de 13 jours, tandis que tous les fruits de la chambre froide CoolbotTM avaient une durée de conservation plus longue de 32 jours. Récolte des fruits le matin ou pré-refroidissement dans la glacière à charbon suivie d'un stockage dans la chambre froide CoolbotTM pour prolonger la durée de conservation des mangues récoltées. Une bonne gestion de la chaîne du froid peut être adoptée par les agriculteurs qui font l'agrégation des fruits pour atteindre le bon tonnage pour les acheteurs et la transformation ultérieure.

Mots-clés: Coolbot, refroidisseur évaporatif, basses températures, post-récolte, pré-refroidissement

Introduction

Mango is one of the key horticultural produce in Kenya with significant domestic and export market. Its value has been ranked 2nd after Avocado in the export market as per the 2014 HCD validated report. Despite the high mango production in Kenya, its value has not been fully exploited as a result of high post-harvest losses of up to 25-45% (Gathambiri *et al.,* 2010 and Gitonga *et al.,* 2010). High postharvest losses in mangoes is caused by various factors, namely; inappropriate time of harvest when temperatures are very high and low relative humidity, improper maturity indices and harvesting methods, poor handling during transport, poor storage, postharvest pests and diseases and inadequate ready markets.

Mango fruit is a living organ that continue to respire even after harvesting but with limited source of food reserves (Alfred and Paul, 2013). Mango fruits are very perishable and if not quickly preserved after harvest, their quality deteriorates away very rapidly thus reducing their shelf life (Ndukwu, 2011). The perishable nature of mango fruits is as a result of water loss, change in composition and microbial attack (Ndirika and Asota, 1994).

Low temperatures and high relative humidity is key in reducing water loss from the fruit to the surrounding, suppress enzymatic and respiratory activities leading to ripening and senescence and slow pathological creating a safe environment for fruit preservation (Katsoulas *et al.,* 2011). In contrary, high temperatures and low relative humidity at time of harvest results in water loss causing fruits to shrivel, lowering quality (Deirdre, 2015). An increase in temperature by 10°C increases rate of deterioration in fruits by 2-3 folds (Kader, 2005).

Cold chain is the continuous handling of the produce in cool temperatures for perishable products from harvest until they reach the final consumers (Kitinoja, 2013). Mahajan and Frias (2010) described components of cold chain into seven: on farm cooling, initial cooling, storage, transportation, distribution, retail and consumer with possible temperature management. Proper cold chain management reduces respiration thus lessens perishability, reduces transpiration hence lessens water loss and shriveling, reduces ethylene production and increases resistance to ethylene action slowing ripening and natural senescence, decreases activity of micro-organisms and reduces browning and loss of texture, flavor and nutrients. Cold chains have been used to maintain post-harvest quality of fruits during shipment, marketing and storage before consumption (Oosthuyse, 1995). The use of the cold chain is often avoided by smallholder farmers due to its perceived complexity in technological know-how and logistical challenges, for example the cost for infrastructure. There are various other options for cold chain among smallholder farmers; namely harvesting produce during cool hours of the day, precooling under tree shade, evaporative cooling and refrigeration. Most of these practices and technologies cannot work in isolation and some are expensive in cost and require electricity/energy which most smallholder farmers cannot afford.

Maintaining a cold chain from the time of harvest to the consumer is key in maintaining quality of harvested fruits and vegetables (Kitinoja, 2013). There is a need to promote awareness, capacity building and training in the proper use of the cold chain. Demonstration on proper cold chain management is one way of showing casing importance of keeping mango fruits under cool environment from harvesting to the consumer. Harvesting early in the morning when plant cells are turgid minimizes water loss. 25-30% postharvest losses are recorded in un-precooled commercial fruits and vegetables while only 5-10% postharvest losses are recorded for precooled ones (Yang *et al.,* 2007). Pre-cooling soon after harvest (before storage) using alternative low cost evaporative cooler (Charcoal cooler) to remove field heat will ultimately affect the shelf life of mango fruits. Evaporative charcoal cooler can be fabricated with locally available materials well adapted to the environment. Cooling requirements will vary with the air temperature during harvesting and stage of maturity. Cold storage (temperature of 10-15°C) in the Coolbot™ cold room after pre-cooling extends mango shelf life (Karithi *et al.,* 2016). The CoolbotTM cold room is of low cost as compared to conventional cold room which most smallholder farmers cannot afford. Proper cold chain management will regulate the fresh market by avoiding glut and distress sales (fetches better prices), thus prolonging the market period and making the food available in off-season. Cold storage is also key in provision of mango fruits for later processing. The objective of this study was to evaluate the effect of proper cold chain management from harvest to storage in preservation of the post-harvest quality of mango fruits.

Materials and Methods

Study site. The study was conducted in Karurumo area, Runyenjes sub-county, Embu County. Embu County is located in a medium potential region, agro-ecological zone (AEZ) III. It receives total annual rainfall of averagely 1067.5mm (received twice in a year), altitude of 700m-6500m above sea level and the temperatures ranges from 26 ^{o}C-35^{o}C (Jaetzold and Schmidt, 1983).

Experimental design. Homogenous mature green mango fruits of 'Kent' variety were harvested at two different times of the day from 3 selected farms. Fruits were harvested at two different times of the day, morning and midday. Firstly, fruits were harvested in the morning (8am), transported to the experimental site and sorted for uniformity. They were then placed in open crates and stored under ambient conditions (25^{o}C) and in the coolbotTM cold room 12 (±2)^{0}C. Secondly, fruits were harvested at midday (12pm), transported to the experimental site and sorted for uniformity. They were then divided into two batches. One batch was stored under ambient conditions (25^{o}C) while the 2nd batch was precooled in evaporative charcoal cooler until temperatures stabilized at temperatures of 22.5^{o}C then stored in the coolbotTM cold room with temperatures of 12 (±2)^{0}C. The experiment was laid down as a completely randomized design (CRD) with a factorial arrangement of 2 treatments (Farmer's practice and recommended practice) and 2 factors (Harvest time and storage options) with 3 replicates each.

Data collection. Analysis of physical and physiological attributes associated with ripening was determined using 3 fruits randomly sampled after every 4-5 days. Pulp temperatures were recorded after every one hour for precooled fruits till temperatures stabilized while temperatures in the CoolbotTM cold room and ambient room were recorded using real-time digital data loggers. Cumulative weight loss was determined using digital weighing scale (Model Libror AEG-220, Shimadzu Corp. Kyoto, Japan) and calculated using the formula: % cumulative weight loss =100 x (Initial weight – Final weight)/Initial weight. Peel and flesh colour was using a Minolta color meter (Model CR-200, Osaka, Japan), color coordinates were obtained (L*, a* and b*) then the hue angle (h°) were calculated by converting a* and b*according to McLellan *et al.* (1995). The peel and flesh firmness were taken using a penetrometer (Model CR-100D, Sun Scientific Co. Ltd, Japan) fitted with a 5mm probe. For the flesh firmness, the probe was allowed to penetrate to a depth of 1cm and the corresponding force required to penetrate this depth determined. Firmness was expressed as Newton (N) (Jiang *et al.,* 1999). Total shelf life of the mango fruits was determined by counting number of days taken to reach the last stage of ripening/remained saleable (Pila *et al.,* 2010).

Data analysis. The data collected were analyzed using Genstat 15th Edition statistical program. Analysis of Variance (ANOVA) was used to test for significant differences among different cold chain practices (Farmer's practices and recommended practices) for each parameter and means separated using Fischer's Protected least significant difference at P=0.05.

Results

Pulp temperatures. Fruits harvested at midday recorded high pulp temperatures (29.2°C) as compared to fruits harvested in the morning (18.9°C). Pulp temperatures of fruits harvested at midday and precooled stabilized at 22.5°C after 6 hours at a rate of averagely 1°C/Hour (Figure 1). Pulp temperatures for all fruits in storage changed depending on storage temperatures till the final day. There was a significant difference ($P<0.05$) in pulp temperature for fruits in cold storage and those in ambient storage. There was no significant difference ($p>0.05$) between fruits that were precooled in the charcoal cooler and stored in the CoolbotTM cold room and those harvested in the morning and stored in the Coolbot™ cold room (Figure 1).

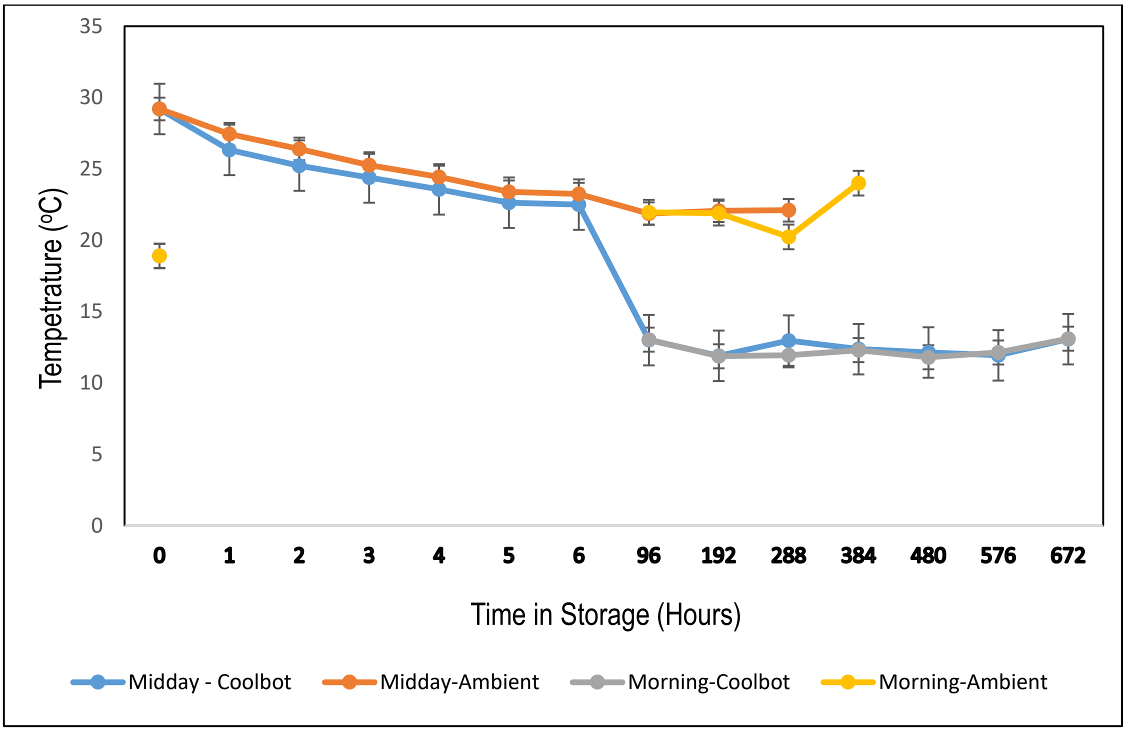

Figure 1. Effect of cold chain management (harvest time and storage option) on fruit pulp temperatures

Physiological weight loss. Physiological weight loss was recorded to be high in fruits under ambient storage, especially those harvested at Mid-day. There was no significant difference ($p>0.05$) between fruits under cold storage despite the difference in harvesting times (on the final day those harvested in the morning recorded 9.7% and 10.5% for fruits harvested at midday). The fruits stored at ambient conditions recorded the highest weight loss, cumulatively 13.3% for those harvested in the morning by the 17th day and 12.6% for the fruits harvested at Midday by the 13th day (Figure 2).

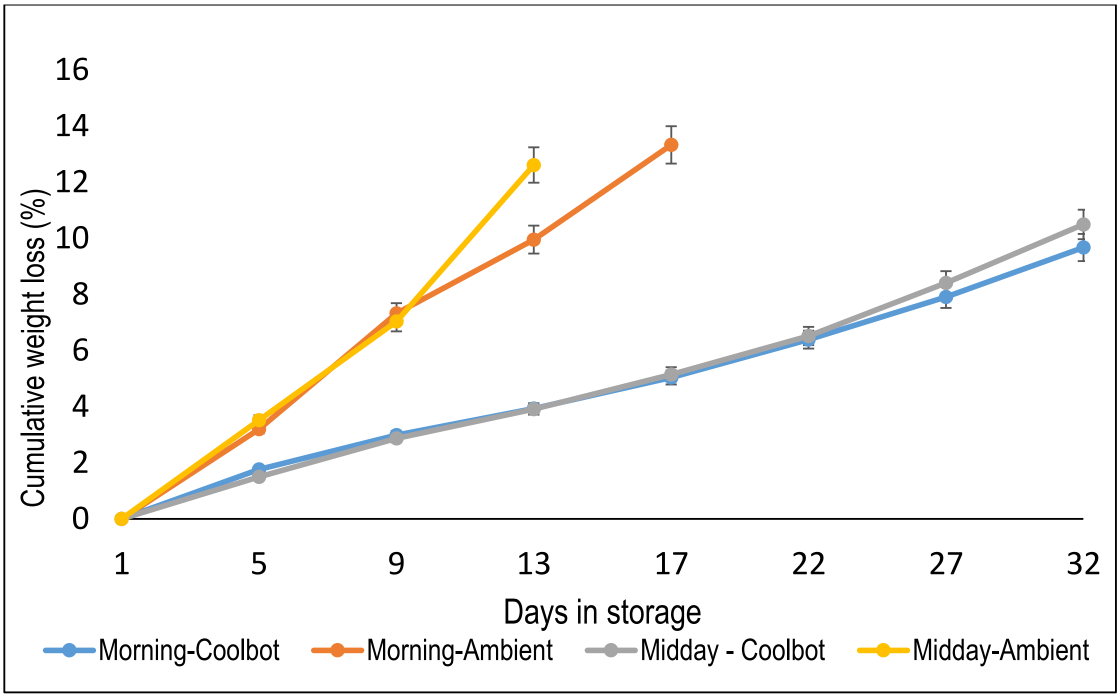

Figure 2. Effect of cold chain management on fruit weight loss

Peel and flesh colour. The peel colour did not change as the fruit ripened while the flesh colour gradually changed from whitish yellow to yellow, a characteristic of 'Kent' variety. Hue angle for flesh colour of fruits under ambient storage steadily decreased as compared to those under cold storage.

Peel and flesh firmness. Peel and flesh firmness (Newtons) decreased as the fruits ripened, irrespective of the treatment. Peel firmness of fruits harvested in the morning and stored under ambient conditions decreased from the initial 147.1N to 31.6N at the end of the storage while for fruit harvested in the morning and stored in the CoolbotTM cold room decreased from initial 147.1N to 35.7N on the final day. Peel firmness of fruits harvested at midday and stored under ambient conditions decreased from initial 145.4N to 33.6 on the final day of storage while for fruits harvested at midday, precooled and stored in the Coolbot™ cold room decreased from initial 145.4N to 39.5N.

Flesh firmness of fruits harvested in the morning and stored under ambient conditions decreased from initial 54.2N to 4.03N on the final day of storage while fruits harvested in the morning and stored in the Coolbot™ cold room decreased from initial 54.2N to 3.97N on the final day of storage. Flesh firmness of fruits harvested at midday and stored under ambient conditions decreased from initial 53.7N to 3.3N on the final day of storage while for fruits harvested at midday, precooled and stored in the CoolbotTM cold room decreased from initial 53.7N to 4.3N at the end of the storage.

Total Soluble Solids. Total Soluble solids increased as the fruits ripened despite the treatment. TSS for fruits harvested in the morning and stored under ambient conditions increased from initial 6.7 oBrix to 15.3 oBrix at the end of storage while for fruits harvested in the morning and stored in the Coolbot™cold room increased from initial 6.7 oBrix to 14.6 oBrix at the end of storage. TSS for fruits harvested at midday increased from initial 6.7 oBrix to 13.7 oBrix and 14.3 oBrix at the end of storage for fruits stored under ambient conditions and cold storage respectively.

Overall shelf life. The overall shelf life was calculated by counting number of days to a pre-determined end stage for the fruits (acceptable at the market). Fruits harvested in the morning and stored under ambient conditions had a shelf life of 17 days while fruits harvested in the morning and stored in the Coolbot™ cold room had a shelf life of 32 days. Fruits harvested at midday and stored under ambient conditions had a shelf life of 13 days while fruits harvested at midday, precooled and stored in the Coolbot™ cold room had a shelf life of 32 days.

Discussion

Cold-chain management is critical in reducing post-harvest losses in mangoes through lowering down respiration rates and other metabolic reactions which are major contributors to the deterioration processes. Fluctuating temperatures experienced in ambient conditions had a negative effect on shelf life and quality of mangoes stored under such conditions. Fruits in the Coolbot™ cold room with semi-constant temperatures lost less physiological weight, had less shriveling and remained firm for longer. Temperature management in order to maintain a proper cold-chain for fresh horticultural produce is key in reduction of post-harvest losses resulting from ripening and senescence (Katsoulas *et al.,* 2001; Atanda *et al.,* 2011). Similar findings were recorded with 'Apple' Mangoes (Karithi *et al.,* 2016) and French beans (Nunes *et al.,* 2001).

Harvest time had an effect on the quality of stored mango fruits due to the prevailing environmental conditions (Temperatures and Humidity). There was an equilibrium between the pulp temperatures and the ambient temperatures leading little/no water loss for fruits harvested in the morning hence maintaining the fruit quality. Earlier studies have shown that outside temperature is one of the main harvest conditions that affect fresh produce quality and shelf life (Yildiz, 1994).

Precooling is necessary in order to remove field heat (Kathryn and James, 2004). Precooling and later storage in the CoolBot™ cold room extended the shelf life of mangoes by a similar margin to those mangoes harvested in the morning and stored in the CoolBot™ cold room. Before harvest, losses due to respiration and transpiration are compensated by the parent plant. After harvest (Separation from parent plant), field heat should be removed immediately in order to reduce water loss, delay ripening and senescence and prevent or delay decay of mango fruits (Finger *et al.,* 2007). Precooling also improves cold-resisting ability, avoids chilling injury on fresh produce (Thompson *et al*., 1998). Rapid removal of field heat before storage is critical to remove heat load for efficient running of the cold storage facility.

Physiological loss in weight of fruits was as a results of biochemical changes e.g. respiration and transpiration that occurs in harvested mango fruits (Thinh *et al.,* 2013). Reduced cumulative weight loss rate for fruits in cold storage is attributed to minimal water loss from the fruit which was as a result lower temperatures and high relative humidity around product. This creates a low vapor pressure deficit (VPD) for the fruits and the area around the fruit, leading to slowed physiological weight loss which finally led to extension in shelf life. Waskar and Masalkar (1997) also reported that increase in PLW of mango fruits was at faster rate during storage at ambient temperature than that of cold storage. Higher temperatures results in greater weight loss of fruits causing the fruits to lose quality by shriveling (Rathore *et al.,* 2007).

The decrease in Hue angle was steady in fruits under ambient storage. The decrease in Hue angle for fruits under cold storage can be attributed to low temperatures which may have caused reduced ethylene biosynthesis, the ripening hormone. Biosynthesized ethylene triggers activities of enzymes responsible for ripening, for example chlorophyll oxidase which degrades chlorophyll (Beaudry, 2000). Artes *et al.* (2006) also attributes colour change to delay in the biosynthesis of anthocyanins and carotenoids resulting from the reduced metabolic processes.

Conclusions

Proper cold chain management can help reduce post-harvest losses by extending 'Kent' mango shelf life. Harvesting mangoes in the morning and storage under low temperatures significantly extends the mango shelf life. Precooling in evaporative coolers to remove field heat and later storage in CoolbotTM cold room is also the other option for fruits harvested when the temperatures are high.

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