GUAVA FRUITS COATED WITH PRE-COOKED MAIZE MEAL HAVE A LONGER SHELF LIFE

Ndoro L. L., Omami E., Chiveu C. J.
University of Eldoret, School of Agriculture and Biotechnology, Seed Crop and Horticultural Sciences Department, P.O. Box 1125- 30100, Eldoret
Corresponding author: liliandoro@gmail.com

Abstract

Guava being a climacteric fruit exhibits high respiration and ethylene production, which hastens its senescence during postharvest handling. A survey was conducted in four agro ecological zones in Taita Taveta County of Kenya; namely Wundanyi (Upper midland; UM 3), Mwatate (Lower midland; LM 4), Taveta (Lower midland; LM 5 both irrigated and rain fed) and Voi (Inner lowland zone) to determine the extent of postharvest losses and storability of guava fruits of different flesh colours. Consequently, a laboratory experiment was conducted at The University of Eldoret, Department of Seed, Crop and Horticultural Sciences to determine the storability of differently fleshed guava fruits under different treatments. The experiment was laid under completely randomized design and replicated five times. The treatments consisted of distilled water, lemon juice, various concentrations of nitric oxide (0.5, 2.0, 3.5, 5.0, 6.5 and 8.0%) and precooked maize meal made from maize flour. In each of the solutions of distilled water, lemon juice and nitric oxide, 25 fruits each of red and white flesh colours were dipped for 10 min and thereafter removed. Similarly, 50 fruits were fully coated with precooked maize meal. Changes in diameter and weight were recorded daily until the last day the fruits remained consumable. Survey results indicated majority of the farmers (97.9%) experienced postharvest losses of which 40% reported the fruits to take a maximum of 5 days to spoil after harvesting. Guava fruits coated with precooked maize meal kept for 13 days. A concentration of 3.5 % nitric oxide was found to keep fruits for longer up to the 8th day of storage. Notably, both red and white fleshed fruits coated with precooked maize meal recorded the least shrinkage index across the storage period. In conclusion, guava fruits can be kept for longer using precooked maize meal. However, an anti- browning and anti- mold agent should be added to the flour.

Key words: Guava storability, Pre-cooked maize meal, Weight loss, Shrinkage Index

Introduction

Guava *(Psidium guajava L.)* is a minor tropical fruit belonging to the family Myrtaceae (Sisir, *et al.,* 2012). The crop is valued for its nutritional importance and medicinal uses. Guava fruits contain important vitamins such as A, B_3, B_6, B_9, C and K. Additionally, the fruit contains minerals; iron, calcium, magnesium and sodium which are important components for human diet (Yahia, *et al.,* 2019; El-khair, 2018). The leaves have medicinal value (Kumar, *et al.,* 2021).

Guava fruits are round or oval and are eaten fresh at two stages: mature green and fully ripe (Adel, 2014). At the fully ripe stage, the flesh colour varies from white to bright red, with light to bright yellow skin (Reddy, *et al.,* 2016). Guava fruits suitable for processing into various products are harvested not earlier than 16 weeks after flowering (Yusof, *et al.,* 2008). Functional products such as guava cheese, a healthy fruit snack, semi-solid concentrate have been formulated using guava puree, added sucrose, chia seeds and almonds (Priyanka *et al.,* 2016).

In Kenya, Horticultural Crops Development Authority (HCDA) (currently Horticultural Crops Directorate (HCD)) reported 412 Ha of land was under guava production which produced about 3000 metric tons of fruits (HCDA, 2016). The area under production increased to 500 Ha in the year 2017 resulting to an increase in fruit production by 9.9%. Leading counties in guava production in Kenya include Mandera, Makueni and Vihiga contributing 35.0, 20.0 and 6.8 percent respectively to the total guava production. Taita Taveta is among the leading counties, ranked 9th contributing 1.9 percent. Limited knowledge in postharvest practices among others has been cited as a major challenge to increased guava production in Kenya (HCDA, 2017).

The fruit is highly perishable with a high respiration rate of 2.24 mmol CO_2 kg^{-1} h^{-1} and ethylene production rate of 0.20 μmol C_2H_4 kg^{-1} h^{-1}, after 156 hours of storage (Bron, *et al.,* 2005; Ribelro, *et al.,* 2014). As a climacteric fruit, guava has a relatively short shelf life of about 6 days at ambient conditions because of its intense metabolism during ripening (Ishartani, *et al.,* 2018). This has limited the time available for marketing and long distance transport from the production areas. In Kenya, for instance, guava fruits are mainly left under the trees to rot (Katumbi, *et al.,* 2021).

Globally, about 1.6 million tons of guava are produced per year, but the utilization is very low due to postharvest losses. For instance in Pakistan, it has been reported that about 20-40% of guava fruit losses occur due to improper management of postharvest operations and lack of advanced postharvest techniques (Said, *et al.,* 2017). In South Africa, short shelf life is among the restrictions in guava production industry. In North Western Ethiopia, postharvest losses during harvesting, storage and transportation account for 18- 28% having storage losses being higher than transportation and marketing (Bantayehu, *et al.,* 2017; Sukhvinder, 2010). Postharvest losses of fruits and vegetables in Kenya have been approximated to 40- 50% (Njeru & Wainaina, 2018).

Various methods have been used to extend the shelf life of fresh fruits. Ozonation has been used successfully to extend the shelf- life of guava fruits up to 30 days. However, its effectiveness is influenced by factors such as presence of steam and humidity level thus micro-organisms must be in a certain condition of swelling to be attacked (Castillo, *et al.,* 2003; Nandaniya, *et al.,* 2017). This method is also expensive hence not affordable to common farmers in Kenya who have low income. Chlorine-based solutions have been used to extend the storage of fresh fruits. However, chlorine has been associated with formation of carcinogenic compounds which are detrimental to human health. At high levels, taste and odour defects on fruit commodities occur (Baskaran, *et al.,* 2013). Sulphur dioxide, a compound necessary for inhibiting pathogen growth during postharvest handling induces injuries in fruits. Sulphite residues pose health risk to the consumers (Palou, *et al.,* 2010).

Modified atmosphere packaging has been successfully used to extend the shelf life of guava. However, shortcomings such as risks of developing anaerobic pathogenic flora are unknown. Most of the plastic films are undesirable to the environment (Irtwange, 2006; Sivakumar & Korsten, 2006) hence there is a need to reduce postharvest losses using eco- friendly compounds while reducing negative effects to human health.

Nitric oxide (a food additive) suppresses the production of ethylene gas, reduces the rate of respiration and reduce ion leakage during postharvest handling. Successful application of nitric oxide has been reported in fruits such as apple, banana, kiwifruit, mango, peach, pear, plum, strawberry, tomato, papaya, loquat, Chinese winter jujube fruit and Chinese bayberry. However, there is inadequate information on the usage of correct nitric oxide concentration to enhance the shelf life of guava fruits of different fleshed colours. Lemon juice contains citric acid which gives it a sour taste. Citric acid lowers the pH upon application during postharvest handling hence decreasing aerobic organisms. Citric acid also prevents browning of fruits by reducing the respiration rate during fruit storage. Lemon juice is readily available to the farmers and also cost effective.

Edible coating improves the appearance of fruits after postharvest handling. It acts as a barrier for moisture and gasses thus it slows down the respiration, senescence and enzymatic oxidation processes during postharvest handling. Additional, edible coated fruits retain colour, texture and volatile compounds. It protects the fruit from attack by pathogens since the fruit is enclosed thus minimal contact with pathogens found in the environment. The focus of this research was therefore (1) to determine the extent of postharvest loss of guavas in different agro ecological zones of Taita Taveta County of Kenya and (2) to determine the effect of various postharvest compounds on postharvest shelf life of guava fruits of different flesh colours.

MATERIALS AND METHODS

Study area

This study was carried out in Taita Taveta County (Coastal region), within four sub-counties (Mwatate, Taveta, Voi, and Wundanyi) located in different agro-ecological zones. According to the 2019 national census, Taita Taveta has a land area of 17083.9 km2 and a population of 340, 671 people (KNBS, 2019). The region's rainfall and terrain vary, with lowland zones receiving an average of 440 mm of rain per year and highland parts receiving up to 1900 mm. The county has two rain seasons: long rains between March and May and short rainfall between November and December, resulting in two fruiting seasons (ICPAC, 2019). The elevation ranges from 500 to 2228 meters above sea level. (MoALF, 2016).

Survey

A survey was conducted in four agro ecological zones in Taita Taveta County of Kenya; namely Wundanyi (Upper midland; UM 3), Mwatate (Lower midland; LM 4), Taveta (Lower midland; LM 5 both irrigated and rain fed) and Voi (Inner lowland zone). The study was carried out in the months of August to September 2019. Stratified random sampling was used where each agro-ecological zone formed a stratum. Within each stratum, random sampling of farms cultivating guava was done following administrative borders. Both closed ended and open ended questionnaires were used to collect data on the extent of postharvest losses in guava and the duration fruits take to spoil. A total of two hundred and ninety-three respondents were interviewed.

Experimental design

Guava fruits of different flesh colours were collected for eventual postharvest experiment in the laboratory. Prior to the laboratory experiment, fruits were sorted according to size, skin colour and flesh colour. Initial fruit weight and fruit diameter were also taken using an analytical balance and a vernier caliper, respectively. The experiment was conducted at the Department of Seed, Crop and Horticultural Sciences Laboratory, University of Eldoret, Kenya. The postharvest treatments consisted of nitric oxide at various concentrations (0.5, 2.0, 3.5, 5.0, 6.5, 8.0%), lemon juice extract and precooked maize meal. In each of the various concentrations of nitric oxide and in lemon juice extract, 25 fruits of white and 25 red fleshed fruits were dipped for ten minutes. Similarly, 50 fruits (25 white fleshed and 25 red fleshed) were fully coated with precooked maize meal. The experimental units were then arranged in a completely randomized design replicated five times having 25 fruits in each treatment.

Data collection

The changes in diameter on different days of storage under different treatments were recorded and expressed in percentage as shrinkage index from the initial diameter using the formula below;

$$SI = \frac{D_0 - D_1}{D_0} x100$$

where SI= Shrinkage index
D_o= Initial diameter
D_1= Diameter at days' interval after application of treatments at storage

Fruits were weighed using a weighing balance and the weight recorded in grams. Physiological loss in weight after applying treatment was calculated using the formula below;

$$PLW = \frac{P_0 - P_1}{P_0} x100$$

where PLW= Physiological loss in weight
P_0 = Initial weight
P_1 = Weight at days' interval after application of treatments at storage

Data Analysis

Data obtained from survey was analysed using SPSS VS 20.0 (IBM, 2011) to determine extent of postharvest losses experienced by farmers in Taita Taveta. Cross tabulations were computed for postharvest storability of guava fruits across the agro ecological zones. For postharvest storability of guava under different treatments, shrinkage indices and physiological loss in weight were computed and subjected to analysis of variance using R-statistical software. The means were separated by Tukey's test at 95% confidence level.

RESULTS AND DISCUSSION

Most of the respondents (97.9%) affirmed to experience postharvest losses (Table 1), with majority of the farmers (40%) across all the agro ecological zones reporting that fruits took an average five days to spoil. However, majority of the farmers (34.36%) from the lower midland (LM 5) irrigated affirmed the fruits to keep for 4 days.

Fruits coated with precooked maize meal recorded the least shrinkage indices compared to the other treatments across the storage period for both the red and white fleshed guava (Figure 1). A concentration of 3.5% nitric oxide recorded the least shrinkage index compared to higher concentrations of nitric oxide at the 8^{th} day of storage for the red and white fleshed guava (Figure 1). Lemon juice treated fruits kept for 10 days. For the white fleshed, lemon juice treated fruits recorded lower shrinkage index than control (0 NO) at the initial storage period of four days whereas the reverse was recorded for red fleshed guava (Figure 1).

Edible coated fruits recorded higher physiological loss in weight for both the red and white fleshed guava at the initial storage period (Figure 2). However, from the 7^{th} day onwards less weight loss was recorded for both the red and white fleshed coated fruits compared to other treatments. A concentration of 3.5% nitric oxide recorded the least weight loss compared to high nitric oxide concentrations at the 8^{th} day of storage for both the red and white fleshed guava fruits. Lemon juice treated white fleshed guava fruits recorded low weight loss compared to control at the initial storage period whereas for the red fleshed guava slightly higher weight loss was recorded (Figure 2).

Table 1. Farmers report on guava postharvest losses and the period taken for fruits to spoil after harvest in four agro ecological zones of Taita Taveta County of Kenya.

Agro Ecological zone	Sub County	Guava postharvest losses (%)	Guava fruit shelf life									
		Yes	3 days	4 days	5 days	6 days	7 days	8 days	9 days	10 days	11 days	14 days
Upper midland(UM3)	Wundanyi	98.8%	0%	12.9%	38.8%	16.5%	30.6%	0%	1.2%	0%	0%	0%
Lower Midland (LM4)	Mwatate	100.0%	1.0%	8.3%	38.5%	20.8%	19.8%	6.2%	0%	3.1%	1.0%	1.0%
Lower Midland(LM5)_ Rain-fed	Taveta	100.0%	0%	33.3%	55.6%	9.3%	1.9%	0%	0%	0%	0%	0%
Lower Midland(LM5)_Irrigated	Taveta	100.0%	22.9%	34.3%	31.4%	2.9%	8.6%	0%	0%	0%	0%	0%
Inner Lowland	Voi	90.9%	0%	31.8%	36.4%	13.6%	13.6%	0%	0%	4.5%	0%	0%
Total		97.94%	4.78%	24.12%	40.14	12.62%	14.9%	1.24%	0.24%	1.52%	0.2%	0.2%

Statistical differences were observed for storage duration across the agro ecological zones ($X^2 = 83.314$; df = 4; $p < 0.001$).

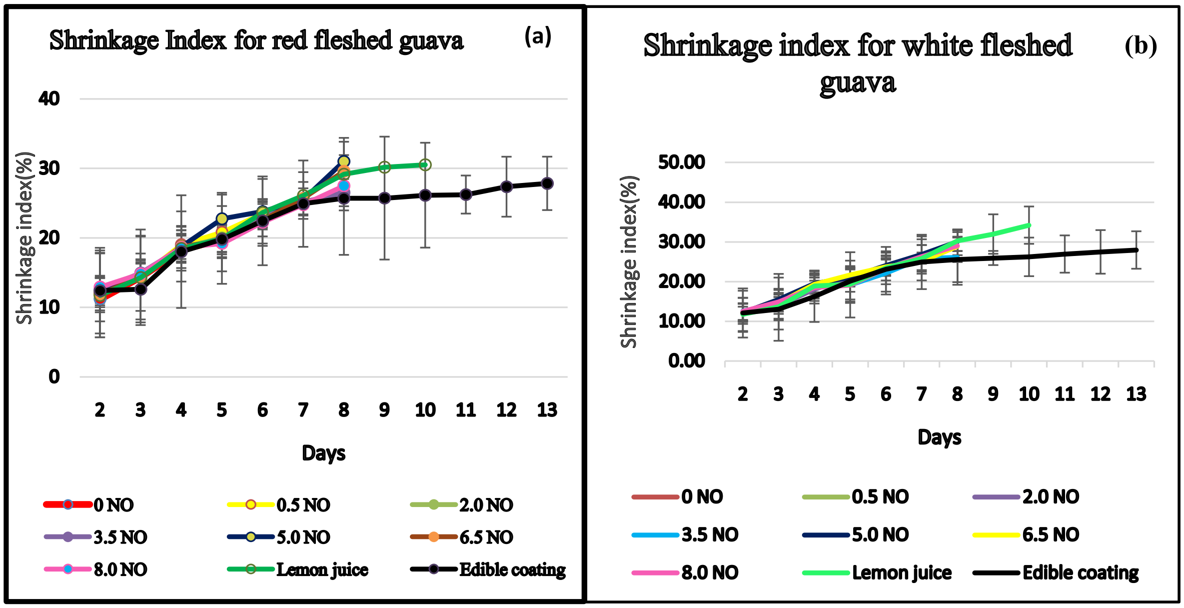

Figure 1: Shrinkage indices for red **(a)** and white **(b)** -fleshed guava fruits under different postharvest treatments.

Discussion

The finding of this study that generally farmers in Taita Taveta County of Kenya experience postharvest losses of about 98% in guava fruits. This loss is immense, especially when compared with other tropical fruits such as Mango which has been reported to have a postharvest loss of 4%, in Kenya (Ambuko, 2020). Gajanana, *et al.,* (2010) reported higher rotting of papaya fruits at the market level. Similarly, Ridolfi, *et al.,* (2018) records postharvest losses of about 10%. In this study, guava fruits had a longer shelf life in the lower midland (LM4) and upper midland (UM 3) compared to the lower midland (LM 5); both rain-fed and irrigated and inner lowland. This is probably due to cool weather which reduces the rates of respiration and water loss at LM4 and upper midland compared to LM 5 and inner lowland which are very hot.

Fresh fruits have been reported to undergo higher postharvest losses in developing countries than in developed nations (Aulakh & Regmi, 2013). This is due to inadequate technology to process the fruits at the farm level. According to FAO, (2018) fruit decay, injury and poor post-harvest practices; rough handling and poor packaging resulted in high post-harvest losses in mangoes. Lack of postharvest management skills and value addition results in higher postharvest losses (Armachius, *et al.,* 2017), which seemed to be the case for guava in this study.

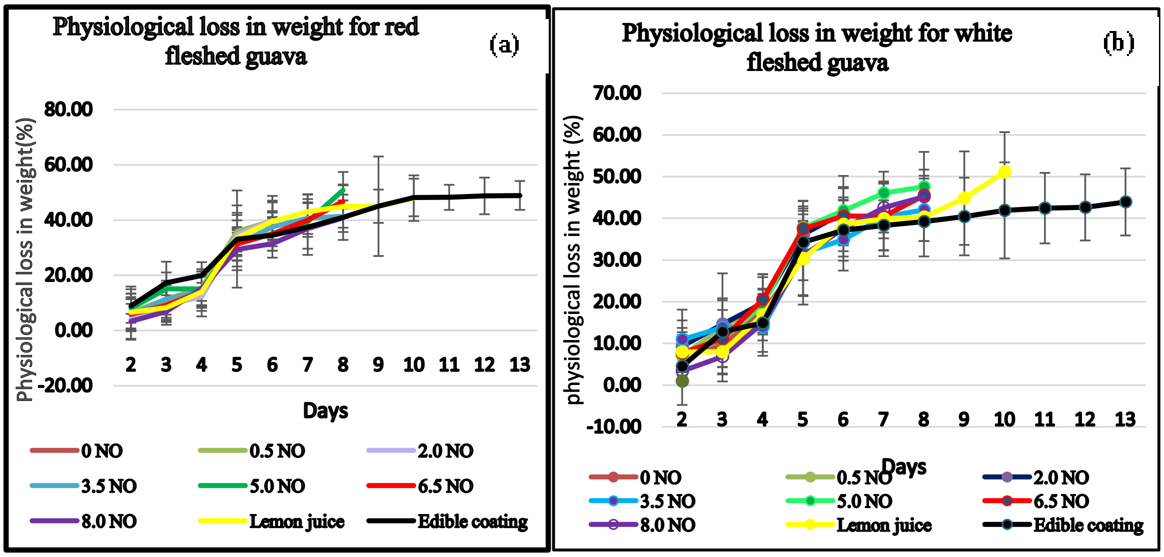

Figure 2: Physiological loss in weight for red **(a)** and white **(b)** –fleshed guava fruits under different postharvest treatments.

The majority of the farmers (40%) reported that the fruit take about 5 days to spoil after harvest (Table 1). This finding was in agreement with this study laboratory finding whereby the fruits in the control treatment (0 NO) took 4 days to spoil. For storage duration, it was observed that the physiological loss in weight and shrinkage index increased irrespective of the flesh colour and treatments. Fruits coated with pre-cooked maize meal kept for a longer period (13 days) followed by lemon juice treated fruits which kept for 10 days. This is similar to the findings of Amrita, (2010) where 100% aloe Vera gel-coated guavas were kept for 15 days. Citrus family (lemon, orange and mandarin) oil have also been reported by Said, *et al.,* (2020) to delay the deterioration of strawberry fruits up to 18 days with minimal weight loss.

Weight loss in fruits is mainly due to respiration, transpiration and some processes of oxidation (Becker & Fricke, 2000; Xanthopoulos, *et al.,* 2017). Low weight loss was recorded by lemon juice treated fruits at the initial storage period of 4 days. Both red and white-fleshed fruits coated with the pre-cooked maize meal recorded the least weight loss at later storage [7th day onwards; Figure 2 (a) and (b)]. It was also interesting to observe a low shrinkage index for both red and white-fleshed fruits coated with pre-cooked maize meal (Figure 1 (a) and (b)). This is in agreement with the findings of Kumar, *et al.,* (2017) who recorded chitosan-coated plum fruits to retain much of their moisture, freshness and kept for a longer time. Similarly, Ankit, *et al.,* (2017) recorded chitosan (1.5%) coated guava fruits to have minimum shrinkage index of 7.37% and reduced physiological loss in weight by 4.83% while maintaining physical quality. The coating reduces transpiration hence water loss since it closes stomata and forms a barrier on the fruit pericarp. Accordingly, Chandrahas & Laxmi, (2016) recorded delayed weight loss for fruits coated with 1% of hydroxypropyl-methyl cellulose and 0.3% palm oil stored at 24±10 ^{o}C for 12 days of storage. This is also in agreement with the findings of Nilesh, *et al.,* (2017) who recorded edible coating (guar gum 1% in the rainy season, paraffin 5% and gum acacia 10% in winter season) to extend the shelf life of guava up to the 10th day of storage while recording a minimum physiological loss in weight. Kannan, (2016) also recorded the coating of guava fruits with 2% corn starch along with 2% neem oil to cause minimum changes in the physiological loss in weight by 2.04% and extended shelf life up to the 16th day. Ola, (2018) recorded the least weight loss percentage in guava fruits treated with 2% edible coating chitosan plus 2% calcium gluconate. Aloe vera gel-coated jujube (Zizyphus mauritiana larmk) fruits (also a climacteric fruit) were able to keep for 15 days while exhibited minimum physiological loss in weight and minimum shrinkage percentage (Arghya, *et al.,* 2017).

Nitric oxide suppresses the release of ethylene gas hence prolonging the shelf life of guava fruits (Hong, *et al.,* 2014). Nitric oxide (5-10 µl/l) has been shown to protect guava fruits from environmental stresses hence acts as a barrier to gas diffusion and moisture loss hence reduced weight loss during postharvest handling (Wills, *et al.,* 2000). According to Tongfei, *et al.,* (2011) ethylene release in tomatoes is suppressed by nitric oxide. Xue-Ping, *et al.,* (2012) reported weight loss in papaya fruits to decrease when treated with nitric oxide and the fruits can keep for 20 days. Shuhua, *et al.,* (2009) reported jujube fruits treated with nitric oxide 10 and 20 µl/l to keep for 12 days. Zheng, *et al.,* (2019) reported grapefruits to store for 30 days when treated with nitric oxide.

At a concentration of 3.5% nitric oxide, guava fruits were able to keep for 8 days in this study. This is similar to the findings of Sahu, *et al.,* (2020) who reported low concentrations of 1.0mM Sodium nitroprusside (a nitric oxide donor) to extend the shelf life of guava up to 12 days having minimal weight loss while retaining the vitamin C content of the fruit. Dalia, *et al.,* (2016) reported 1- methyl cyclopropane treated mango fruits and wax + nitric oxide treated fruits to have less weight loss compared to untreated fruits. Deep, *et al.,* (2018) recorded papaya fruits treated with 2% calcium chloride to keep for long (6 days) and maintain the total soluble solids (TSS), acidity and ascorbic acid content. Less weight loss was also recorded for the combination of 1-MCP with S- nitrosoglutathione in blueberry fruits and the fruits kept for 14 days (Gustavo, *et al.,* 2017). Asghari, *et al.,* (2013) reported sweet cheery fruits treated with 5 and 10 µmol/L nitric oxide and 33% aloe vera gel were able to keep for 30 days under cold storage conditions while maintaining the fruit weight. Gill, *et al.,* (2015) reported guava fruits treated with aqueous hexanal formulation and calcium nitrate to retain fresh weight for 2 weeks.

At high concentrations of nitric oxide (6.5 % and above) the fruits exhibit brownness on the fruit skin. This is in agreement with the findings of Wills, *et al.,* (2000) who recorded strawberry fruits treated with (5000ml/l) nitric oxide to brown around the calyx. On the contrary Loay & Taher, (2018) found Banati guava fruits to brown less when treated with chitosan/ poly- vinyl- pyrrolidine- salicylic acid (2mM). Mahitha, *et al.,* (2018) observed a reduction in physiological loss of weight of guava fruits treated with 2% $Ca(NO_3)_2$. Low physiological loss in weight (1.53%) was recorded by Bhupinder, *et al.,* (2017) on guava fruits treated with silver nitrate (1.5%).

Conclusion

Based on the survey results, high postharvest loss (about 98%) of guava fruits is experienced in Taita Taveta County. Most fruits (40%) were only able to keep well up to day 5 of storage, regardless of the fruit flesh colour. With the application of postharvest compounds, fruits can be kept for a longer period (13 days) when coated with pre-cooked maize meal which is readily available and affordable. Lemon juice treated fruits kept for 10 days. The fruits can be kept for up to 8 days using an optimal concentration of 3.5% nitric oxide.

Recommendation

There is a need to educate the farmers on better postharvest handling methods such as use of the pre-cooked maize meal to prolong the shelf life of the fruits. An anti-browning and anti-mould substances should be added to the pre-cooked maize flour before use.

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