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Harvesting, postharvest handling, hygiene knowledge and practices of guava fruit farmers: A comparative study of two counties of Kenya

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The guava (*Psidium guajava*) grows on farms or in the bush in many parts of Kenya, including Kitui and Taita Taveta, and remains virtually unattended. Guava fruit value chain is commercially disorganized and standard postharvest handling and storage procedures are not practiced as there is no bulk handling. This study evaluated the harvesting and postharvest handling practices of the guava fruit in two counties of Kenya. A total of 417 farmers were selected from the two counties (Kitui, n=214 and Taita Taveta, n=203). Using a structured questionnaire, data was collected utilizing Open Data Kit (ODK). Results showed that the main indicative maturity indices in Kitui and Taita Taveta were skin color (98.59 and 92.12%) and full ripe (38.79 and 18.72%) respectively. Results indicated that no packaging was done at farm level as only small quantities were harvested. Storage period was short (< 4 days) mainly to await consumption as reported by 41.6 and 55.2% handlers in Kitui and Taita Taveta, respectively. A cluster analysis of hygiene and postharvest handling practices indicated that Kitui farmers were more knowledgeable (71.9%) as compared to Taita Taveta (49.8%). Additionally, female farmers were more knowledgeable (65.4%) on postharvest handling than males (55.4%). Postharvest handling practices were informal with little packaging, poor hygiene practices, short term storage and informal marketing of small quantities in both Counties.

Key words: Guavas, postharvest, preservation, postharvest handling, hygiene, postharvest losses.

INTRODUCTION

Guava (*Psidium guajava* L.) is a climacteric fruit belonging to the family Myrtaceae (Chiveu et al., 2017). There are three main varieties of the fruit with different flesh color namely, pink, white and strawberry guavas

(Masud et al., 2018). The fruit is however, highly perishable (Rawan et al., 2017). The major guava growing areas in Kenya include Elgeyo-Marakwet, Kakamega,Uasin-Gishu, Kwale, Kilifi, Meru, Homabay, Siaya, Vihiga, Mombasa, Kitui, and TaitaTaveta among others (Chiveu et al., 2017). Guava trees survive in most agro ecological zones in Kenya except the arid areas (Omayio et al., 2019). The trees grow naturally unattended and grow from seeds dispersed by animals, birds and other agents (Chiveu, 2019).

Guavas are nutritious and have high levels of ascorbic acid, riboflavin (vitamin B2), vitamin A (beta carotene) and minerals like phosphorus, iron and calcium (Jiménez-Escrig et al., 2001). The ascorbic acid content in guavas is 4-5 times higher than that of citrus fruits; 200-400mg per 100g of guava (Augustin and Osman, 1988; Crane and Balerdi, 2015; Naseer et al., 2018). The nutritional quality of guavas is however, affected by the maturity levels and postharvest handling of the fruit (Zhou et al., 2014). The fruit is fragile and is prone to bruising and physical damage (Vishwasrao and Ananthanarayan, 2016). The vulnerability to damage is dependent on the maturity stage and level of ripeness (Kamsiati, 2016). The maturity level at harvest determines the shelf life and ultimate fruit quality (Sharma, 2019). The fruit skin color is mostly used to assess maturity of guavas (Sharma, 2019). They are harvested at color break when they change from green to light green or slightly yellow (Kamsiati, 2016).

Harvested guavas require proper postharvest handling to maintain quality, increase shelf life and reduce losses (Rawan et al., 2017). The guavas should be sorted by separating healthy fruits from bruised, wounded and damaged fruits (Barboza et al., 2016). Quality guavas are washed to remove dirt, dust, field heat and reduce microbial load on the surface. The disinfectants in the water prevent spoilage by bacteria and fungi (Kamsiati, 2016). The fruits can be packaged appropriately and stored to extend shelf life (Sharma, 2019). Manipulation of storage temperature is an effective means to extend the shelf life of guava (Paull and Chen, 2014). They can be stored for 7 days at 20°C and 2-3 weeks at 8-10°C and 85-90% relative humidity (Sharma, 2019). Guava postharvest losses are estimated at 25-30% which is attributed to poor storage and postharvest handling (Krishna and Kabir, 2018). Damage in guava is caused by rough handling, which results in bruises and wounds that makes it susceptible to microbial spoilage (Augustin and Osman, 1988; Singh, 2011). Good handling practices maintain quality of guava and reduce the huge postharvest losses experienced by farmers (Kamsiati, 2016). In Kenya, guava fruit receives minimal processing and value addition leading to neglected postharvest management (Omayio et al., 2019). The guava fruit is normally harvested by handpicking with no sorting or grading, resulting in heavy economic losses (Kamsiati, 2016). The fruit is also attacked by numerous diseases that cause rotting (Soares-Colletti et al., 2015) which reduces its marketability and processing.

Poor postharvest handling has contributed to huge guava postharvest losses in Kenya as the fruit is neglected and farmers mostly depend on natural production (Omayio et al., 2019). There is high production of the fruit in Kenya with minimal utilization due to short shelf life and low marketability (Chiveu, 2019). The study aimed at documenting harvesting and postharvest handling practices and marketing of the guava fruit. Kitui and Taita Taveta counties were selected as they are among the high guava producing areas (Chiveu et al., 2017).

MATERIALS AND METHODS

Study design

The study was cross-sectional in design, comparative between two Counties. Survey was conducted in April and May 2019 in the Counties of Kitui and Taita Taveta. A total of 417 farmers including 214 from Kitui and 203 from Taita Taveta were interviewed. Data was collected using semi-structured questionnaires by utilizing the digital Open Data Kit application. The data related to the harvesting and postharvest handling practices of guavas from the two Counties.

Study area

The study was conducted in Kitui and TaitaTaveta counties. Kitui County (Figure 1) is located in the former Eastern Province of Kenya. It covers an estimated area of 30,496.4 km^2 and comprises of 1.136 million people according to the 2019 Kenya National Bureau of Statistics census (KNBS, 2019). It is located between latitudes 0° 10" and 3° 0" South and longitudes 37° 50" and 39° 0" East. The altitude of the county ranges between 400 and 1800m above sea level (County Government of Kitui, 2018). It has a low lying topography with arid and semi-arid climate. The rainfall distribution is erratic and unreliable except for the highlands which receive relatively high rainfall annually compared to the lowlands. The annual rainfall ranges between 250-1050 mm per annum with 40% reliability for the long rains and 66% reliability for the short rains (Kitui County Intergrated development, 2018). The County

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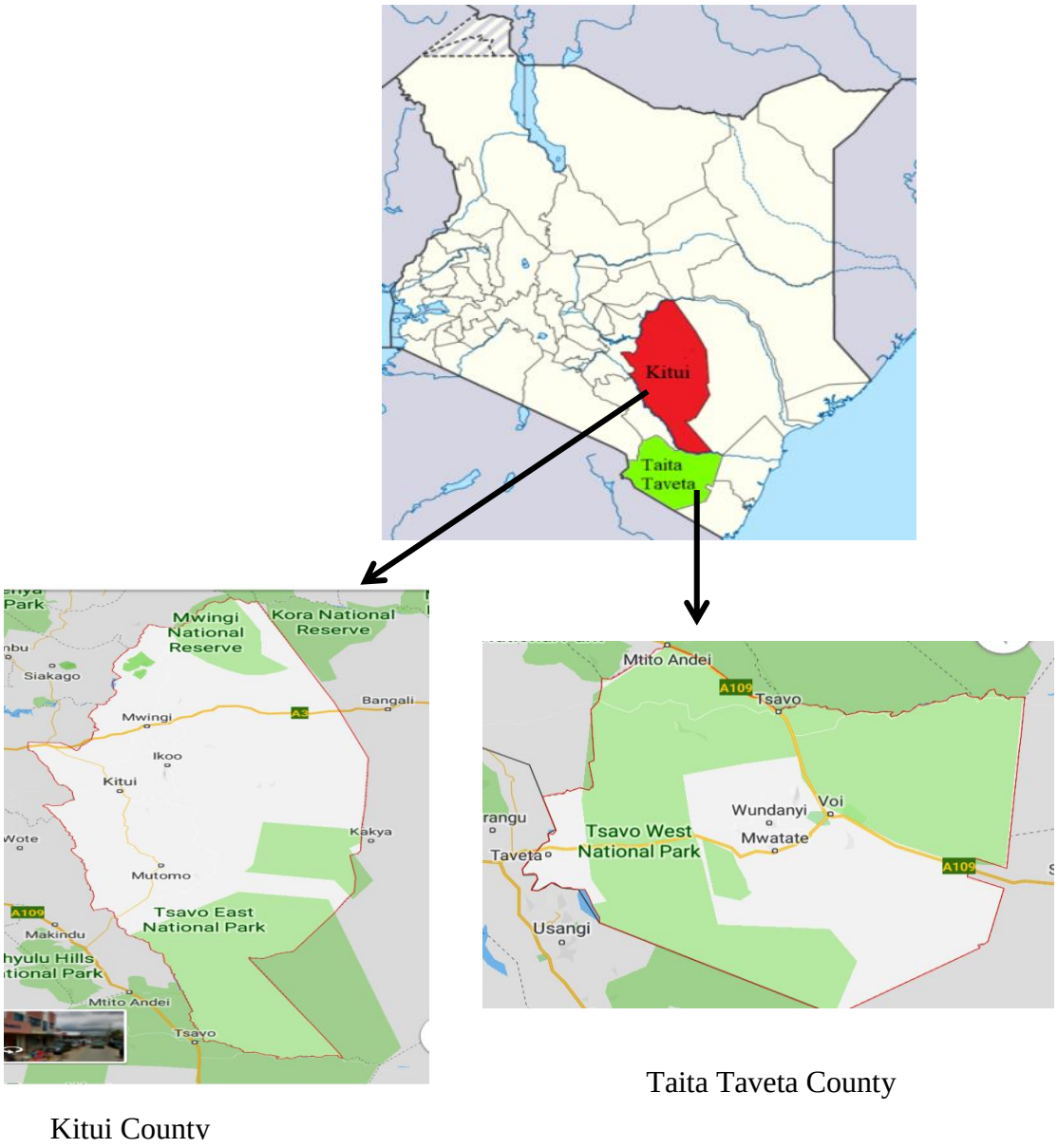

Figure 1. Map of Kenya showing the location of Kitui and Taita Taveta Counties.
Source: Google Maps, (2019).

experiences high temperatures with annual temperature ranges between 26 and 34°C and minimum mean annual temperature ranges between 14and 22°C (Cassim and Juma, 2018). The county is also divided into agro ecological zones which support subsistence crop and livestock agriculture which is the major economic activity(Chiveu et al., 2017). The guava trees grow in the highland areas of the county which has sub-humid climate. Other horticultural crops produced in the county are fruit crops such as mangoes, paw paws, water melons, tomatoes, avocado and castor fruit (Kitui County Intergrated development, 2018). Taita Taveta County (Figure 1) is located in the Coastal region of Kenya bordering Tana River, Kitui Makueni, Kwale and Kilifi, Kajiado and the Republic of Tanzania on the Southern side. The county covers an estimated area of 17,084.1km^2 and has an estimated population of 340,671 persons according to 2019 census (KNBS, 2019). The county lies between longitude 37° 36$^{'}$east and 30°14$^{'}$ east and latitude 2°46$^{'}$ south and 4° 10$^{'}$ south. Altitudes range from 500 m above sea level to almost 2300 m at the highest point in the county Vuria Peak. Taita Taveta is mainly dry, with the exception of Taita Hills which are considerably wet. Rainfall distribution is usually uneven, with higher rainfall amounts being recorded in highland areas as compared to the lowlands. Annually, mean rainfall is 650 mm (County Government of Taita Taveta, 2018). The average temperature in Taita Taveta County is 23°C, with lows of 18°C in

the hilly areas and rises to about 25°C in the lower zones (Tirra et al., 2019). The guava fruit grows in the highlands with Sisal estates and hilltop forests occupying less than 100 km^2.

The Taita hills form the highlands which support agricultural activities. Horticultural activities include fruit crops (bananas, mangoes, oranges, passion fruit, guavas) (County Government of Taita Taveta, 2018).

Study population

The study included farmers in the two Counties. The guava farmers constituted the guava farming households.

Sample size calculation

The sample size for the respondents was determined as per the Fisher's formula (Fisher et al., 1991).

$$N = \frac{Z^2 pq}{d^2}$$

Where;
N -Quantity of sample size desired
P- Proportion of the farmers expected to have guavas in their farms, taken as 50%

q (1-p)- The ratio in the selected population not expected to have guavas in their farms (50%)
d=Level of precision or absolute error (0.048^2)
Z- Normal standard variation at the required confidence level, a 95% confidence level will be used.
Therefore;
N= (1.962^* 0.5*0.5) ÷ ($0.048^{2)}$ = 417 respondents

There was no attrition rate because all respondents returned completely filled forms.

Sampling procedure

A multi-stage sampling was used in getting the sampling units for the study. The two counties were selected due to their high guava production and the fact that the project that funded this study was based there. Two Sub-counties were selected in each County based on high production quantities from which two wards were selected as the study sites. The respective households were then selected randomly and interviews conducted with a respondent in each household.

Hygiene and knowledge practices

Knowledge and hygiene practices scores of the respondents was assessed using the "Yes", "No" and "Don't Know" statements while the practice was assessed using "Yes" and "No" questions. Blooms cut-off point's was used in assessment of knowledge in previous studies by Abdullahi et al. (2016) and Nahida (2008).

Grades of ≤59% were scored as low, 60-79% moderate and 80-100% high. These scores were obtained by summing up correct scores for 1-18 knowledge statements which were categorized with postharvest knowledge having of 10 points and hygiene practices 8 points.

Statistical data analysis

Data analysis was done using statistical package for Social Sciences Software (IBM SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, N.Y., USA) and R package for statistical computing (R Core Team, 2019). Each postharvest handling practice and hygiene knowledge response was transformed and categorized as either correct or incorrect. Frequencies were used to summarize scores for each question on hygiene and practices. Inferential statistics (t-test, chi square, frequencies and correlations) were used to analyze the data. A cluster analysis was done using R for data science to analyze knowledge by clustering the respondents in terms of their levels of knowledge.

RESULTS

Socio-demographic characteristics of guava producing farmers

Guava production in both Kitui and Taita-Taveta Counties largely involved women (57.6%). Taita Taveta had more men (51.72%) involved in guava production as compared to Kitui where there were more women (66.35%) than men (P<0.001). The mean age of guava farmers differed significantly (t (415) =2.2, P<0.05) in both counties with Taita Taveta having aged farmers 48.2±15.9 years as compared to Kitui (44.9±15.7) years. There was no significant (P>0.05) association between county and levels of education of guava producing farmers (χ^2=4.3, P=0.2) with most respondents (58.5%) having attained primary education and 10.1% were illiterate. Although the level of tertiary- educated respondents was low, Kitui had a slightly higher number of farmers who had attained tertiary education (7.5%) as compared to Taita Taveta with only 4.4%. Those who attained secondary level were low in both counties 25.9%. The level of education was significantly associated (χ^2=23.533, P<0.001) with gender with both counties recording more educated women than men. The major source of household income was farming and it significantly differed (χ^2=7.9, P=0.1) in both counties with Kitui (70.9%) and Taita Taveta (74.9%) (Table 1).

Harvesting practices

The harvesting practice is shown in Table 2.

Guava postharvest handling practices

Seven in every ten farmers (70.7%) transported guavas using human labor using sacks, baskets or buckets after harvesting. There were significant differences (χ^2=45.9, P<0.001)in methods of transporting guavas between the counties. Manual transportation of guavas was the most

Table 1. Socio-demographic characteristics of guava handlers in Kitui and Taita Taveta Counties.

Demographic characteristic	Levels	Taita Taveta %	Kitui %
Gender	Male	51.7	33.6
	Female	48.3	66.4
Age of respondents	Mean	48.4	44.9
Level of education	Did not attend school	8.9	11.2
	Primary	57.6	58.4
	Secondary	29.1	22.9
	Tertiary	4.4	7.5
Marital status	Married	74.8	77.6
	Widowed	2.9	7.9
	Divorced/separated	5.4	0.9
	Single	16.8	13.6

Table 2. Maturity indices and harvesting practices by guava farmers in Kitui and Taita Taveta counties.

Parameter		Taita Taveta %	Kitui %
Maturity indices	Color	92.1	87.4
	Fruit sizes	18.7	17.8
	Full ripe stage	31.0	29.4
Immediately after harvesting guava	Keep exposed to sunlight	0.5	15.4
	Keep under shades	53.7	76.6
Washing harvested guavas	Yes	56.2	35.0
	No	43.8	65.0

common means of transportation in Taita Taveta and Kitui with 77.8 and 64.9% of farmers respectively transporting their fruits from the farms using buckets and sacks. The main packaging materials among the farmers who packaged the fruits (Kitui, n= 214, Taita n=203) in Kitui was sacks (29%) paper boxes (39%) in Taita Taveta. The two counties differed in choice of packaging material as shown in Figure 2.

Guava deterioration

On average guavas lasted for 4.1±1.9 days prior to deterioration in both counties. There was a significant difference of guava shelf life between Kitui and Taita Taveta ($t(415) = 8.4$, $P<0.001$) with Kitui having a shorter period (3.4±1.9) compared to Taita Taveta (4.9±1.8). Approximately 76.6% of guava farmers experienced massive postharvest losses which were significantly different ($t(415) = -8.3$, $P<0.001$) between both counties being more rampant in Taita Taveta where 93.1% of farmers reported postharvest losses as compared to Kitui where only 61.2% did. Farmers in both counties reported similar kinds of losses and their major causes as shown in Table 3. Losses from shriveling were higher in Kitui (20.5%). Most of the fruits were left to rot in the fields as shown Figure 3. Approximately 93.8% of farmers experienced pests and diseases with no measures in place to control them. Pests and diseases were more frequent in Kitui (95.3%) than in Taita Taveta (77.8%). Eight in every ten farmers (81.1%) did not have an alternative use for overripe guavas and these were left to rot in the farms (Taita Taveta (84.7%), Kitui (75.7%). Farmers in the two counties used various strategies to

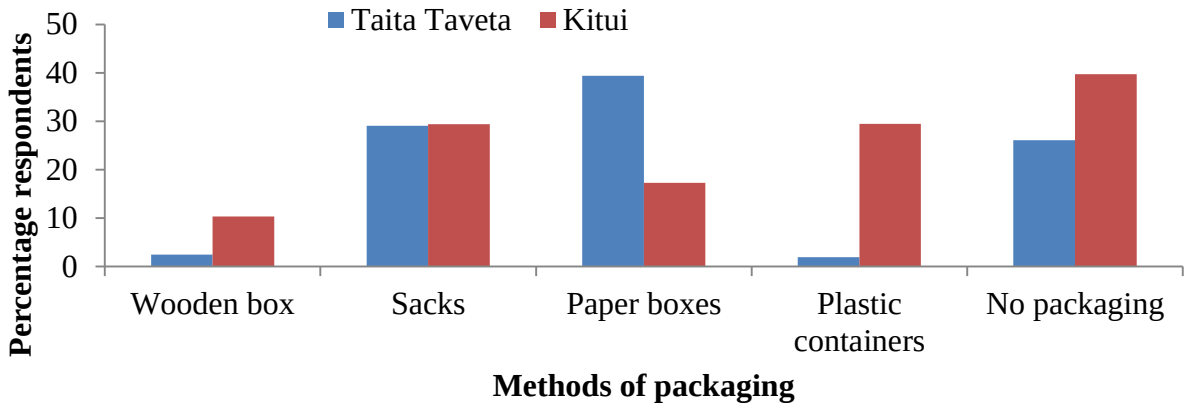

Figure 2. Methods used by farmers for packaging guavas in Kitui and Taita Taveta counties, Kenya.

Figure 3. Picture of a guava rotting under a tree in a farm in Kitui, Kenya. High postharvest losses were reported in Kitui and Taita Taveta as most of the guavas are left to rot in the farm.

reduce guava deterioration with aim of reducing losses (Figure 4).

Storage of guava fruit

In both counties, guavas were mainly stored for later consumption and sometimes for market. More than half of the farmers (55.1%) did not store guavas after harvesting. Slightly more farmers in Kitui (58.4%) stored guava compared with Taita Taveta where more than half (55.2%) did not. This was due to low commercialization of the fruit. A low proportion of farmers practiced guava storage and there was a significant differences (t (415) =2.8, P=0.05) between the proportions of farmers that stored guavas between the two counties as most farmers

Table 3. Types and causes of guava deterioration in Kitui and Taita Taveta counties.

Kinds of deterioration	Taita Taveta (%)	Kitui (%)	χ^2
Mechanical injuries	24.1	21.5	3.1
Over ripening and rotting	87.7	54.6	2.5
Guava shriveling	2.5	20.5	57.1 **
Microbial damage	49.7	30.8	0.3
Causes of guava deterioration in Kitui and Taita Taveta counties, Kenya			
Poor storage	29.6	39.7	4.7*
Pests and diseases	77.8	95.3	27.8**
Inadequate knowledge on postharvest handling	39.5	36.5	0.4
Excess rain	18.7	28.9	5.0*
Lack of market	53.7	12.6	78.9**
Poor packaging	2.9	22.9	36.2**

*Correlation is significant at the 0.05 level, **. Correlation is significant at the 0.001 level (Chi-square tests).

in both counties harvested small quantities. The farmers who stored guavas used various methods of storage (Table 4). There was, however, no significant association between the method of storage and the shelf life of guavas (χ^2=24.439, P=0.041). Farmers employed various strategies of extending guava shelf life which included sorting, harvesting small quantities, cold storage and minimizing mechanical damages (Figure 4). There was a correlation between the shelf life of guavas and the county of origin (r = 0.77, P<0.001) hence the county had an influence on how long guavas stored before spoiling.

Hygiene knowledge by handlers in postharvest handling of guava fruit

Clustering of knowledge on hygiene and postharvest handling practices generated two components that explained more than three quarters of data variability (76.0%) (Figure 5), Cluster one had relatively low mean scores of knowledge on food hygiene, household hygiene, harvesting, storage and packaging (Table 5). This was lower than the scores of cluster two where those with knowledge had relatively higher scores. Kitui had a higher proportion of farmers (71.9%) with knowledge on hygiene and postharvest handling practices as compared to Taita Taveta (49.8%). Furthermore, the female farmers (65.4%) were more knowledgeable than the male farmers (55.4%). The level of education had an influence on hygiene knowledge where a greater proportion of those with knowledge were among the educated farmers who had attained tertiary education (87.5%) compared to those with primary (62.7%) and secondary education (52.8%). The respondents' level of training on hygiene and postharvest practices associated significantly (χ^2= 6.3, P<0.5) with hygiene knowledge on handling of fruits. Farming was the main occupation for both clusters; however, cluster two had the highest number of respondents who were farmers by occupation (60.4%) than cluster one (32.3%). The overall knowledge assessment adopted Blooms cut-off point's grade scores, at P<0.001, t (415) =-6.8, at 95% confidence interval. Kitui county had a higher score (80.8±27.2) compared to Taita Taveta (65.1±19.2) knowledge on post-harvest handling practices. Respondents from both counties had higher knowledge on hygiene practices compared to postharvest handling with Kitui and Taita Taveta scoring a mean of 89.6±17.3 and 81.3±6.3 respectively (t=81.8, P<0.001). Responses on postharvest handling practices rangedfrom 60-79% hence farmers had moderate knowledge on postharvest practices. On hygiene knowledge correct responses were between 80-100% which indicated that the farmers had high knowledge on hygiene. Clustering of knowledge on hygiene and postharvest handling practices generated two components that explained more than three quarters of data variability (76.0%) indicating varying levels of knowledge among guava handlers. Cluster 1(component 1) had relatively low mean scores of knowledge on food hygiene, household hygiene, harvesting, storage and packaging. This was lower than the scores of cluster (component 2) where those with knowledge had relatively higher scores.

DISCUSSION

Socio-economic and demographic characteristics of guava producing farmers

The higher involvement of women in guava production in

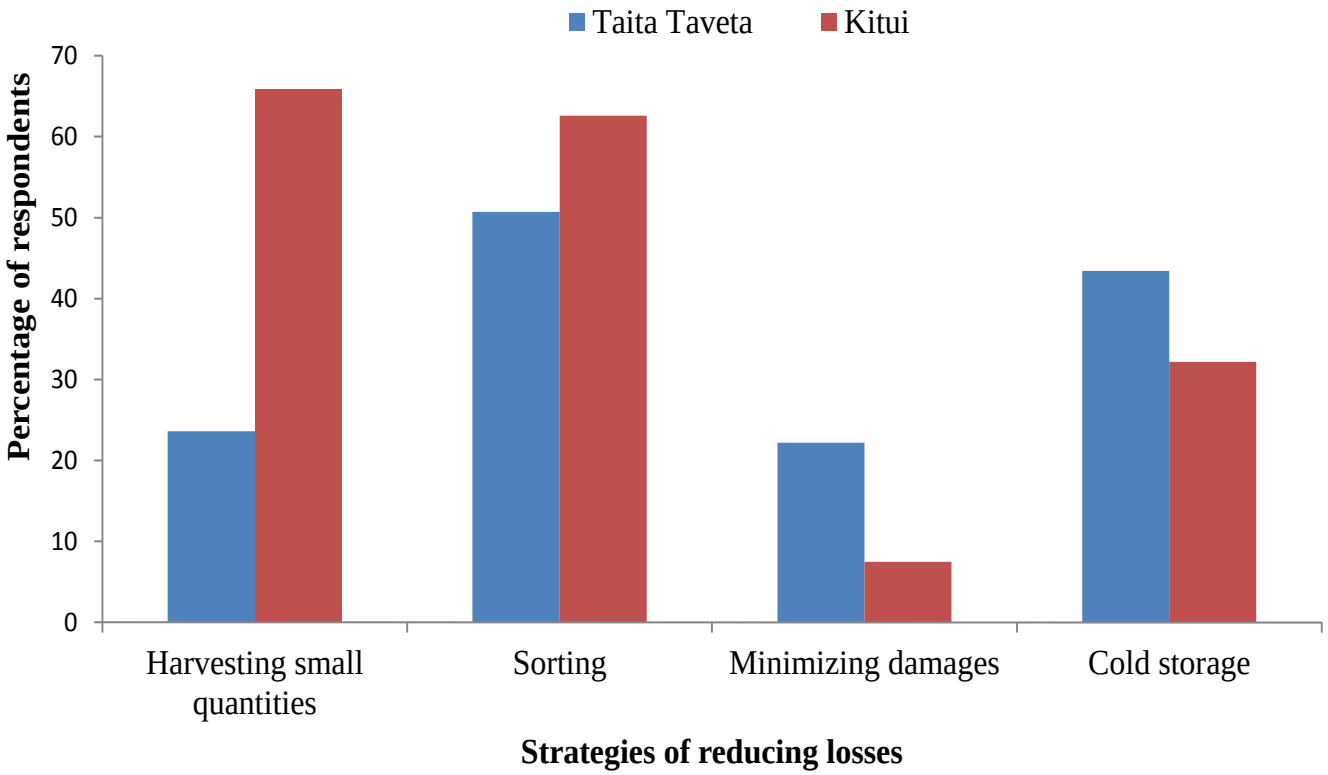

Figure 4. A comparison of the strategies for reducing guava deterioration in Kitui and Taita Taveta counties, Kenya ($\chi 2=149.8$, $P<0.001$).

Table 4. Storage containers used to store guavas by farmers in Kitui and Taita Taveta counties.

Method of storage	Taita Taveta (%)	Kitui (%)	χ^2
Crates	11.3	20.1	6.0*
Sealed plastic bags(Modified atmosphere)	0	14.5	31.8**
Low temperature (Refrigeration)	1.9	26.2	49.5**
Carton/plastic papers	27.1	15.4	8.5*
No storage	55.2	41.6	7.7*

***Correlation is significant at the 0.05 level, **.Correlation is significant at the 0.001 level (Chi-square tests).

both Kitui and Taita Taveta is linked to factors such as societal roles where women are entitled to carry out farm activities especially for subsistence farming (Ogunlela and Mukhtar, 2009). Majority of farmers had low levels of education which is in agreement with other studies that have reported that most people involved in fruits and vegetable production have low education (Rahiel et al ., 2018). This is attributed to lack of interest in education and high poverty levels in the two counties where most of the household income is used to purchase food (Brewer et al., 2017; Tacoli, 2017). Household education influenced their postharvest handling of fruits where low levels of education led to poor handling practices thus increasing guava losses (Sharif and Obaidat, 2013). This was well reflected in Kitui where there were more educated farmers and equally higher knowledge scores on hygiene and postharvest management compared to respondents from Taita Taveta County. Women were found to be more educated than men in both counties as indicated by the number of females who attended school which can be linked to the increased women empowerment in the country leading to increased interest

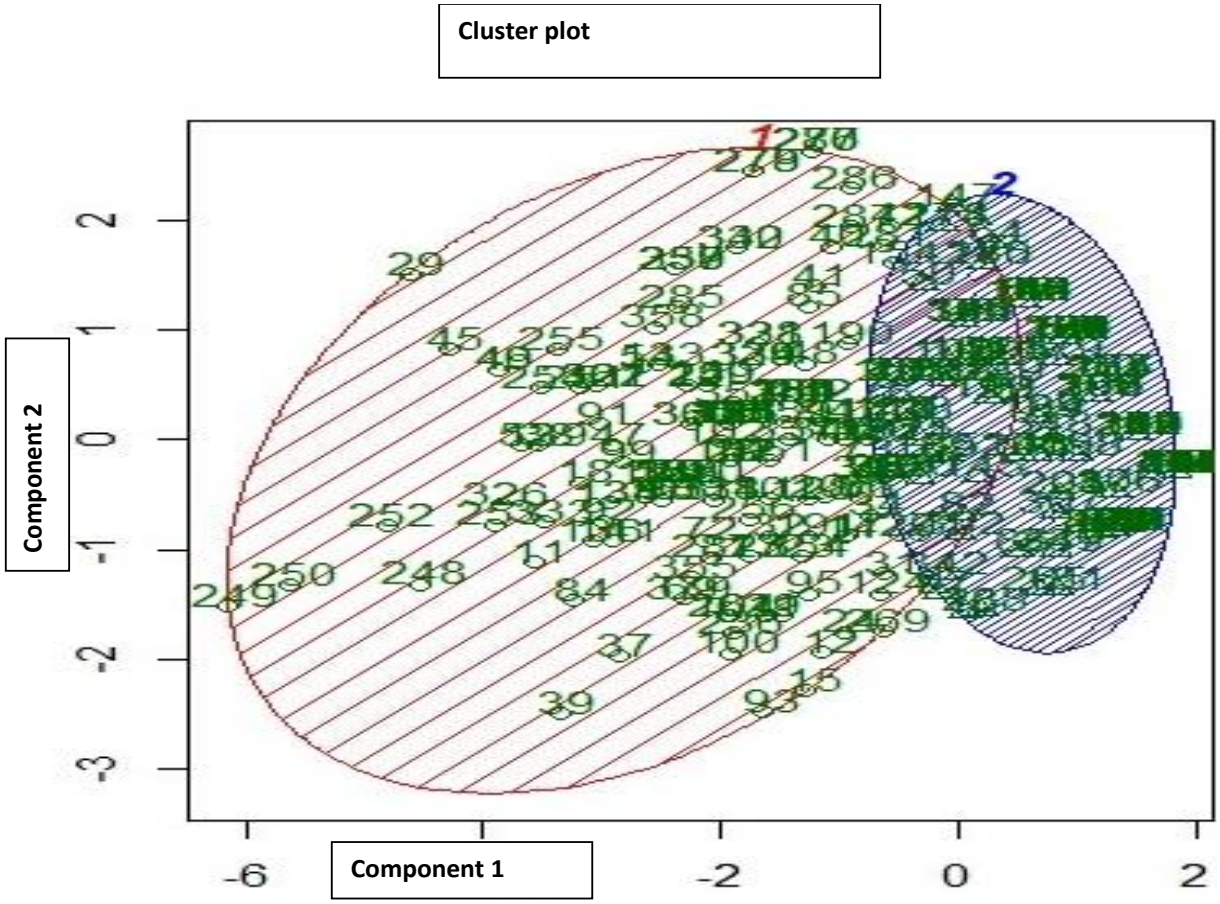

Figure 5. WSS plot of knowledge clustering of farmers in Kitui and Taita Taveta counties, Kenya.

Table 5. General hygiene and postharvest handling knowledge of guava farmers and handlers in Kitui and Taita Taveta counties**.**

Cluster	Food hygiene	Household Hygiene	Harvesting	Storage	Packaging
1	-0.8707538	-0.9238673	-0.7749838	-0.8656509	-0.8767342
2	0.5531847	0.5531847	0.4923427	0.5499429	0.5569841

The means have been standardized to z-distribution with a mean of 0 and standard deviation of 1.

in education (Habib et al., 2019). Socio-economic and demographic characteristics of guava farmers influenced guava production and postharvest handling practices.

Harvesting practices

The maturity stage at harvest has an implication on the shelf life and quality of guava fruit (Cavalini et al., 2006). The maturity indices for harvest of guava fruits is usually based on subjective evaluation of color, fruit size and texture which vary with location, time, fruit size, type and age of the plant (Kamsiati, 2016). In both Kitui and Taita Taveta, guava fruits were harvested when fully ripe. Fruits harvested at full ripe stage are of high quality but has short shelf life, while those harvested at mature green stage tend to have low quality but longer shelf life (Kamsiati, 2016). On the other hand, harvesting of the immature guava fruit results in product losses due to slow ripening or failure to do so (Singh, 2011; Prasad et al.,

2020). In Kitui and Taita Taveta, farmers harvested fully ripe guavas for household use only and the rest were left to rot in the farm which contributed to huge postharvest losses (Omayio et al., 2019). The fruits should be harvested at mature green stage to ensure effective postharvest management (Cantwell and Davis, 2014). The use of skin color as indicator of the maturity of the fruit in both counties is in agreement with the findings reported by Singh (2011) in his study on guavas which indicated that color is a determinant of maturity in guavas. Additionally, this technique is employed in establishing maturity in several fruits including mangoes, bananas, papayas (Cantwell and Davis, 2014). Removal of field heat from guava fruits was a common practice in both regions by washing or keeping the fruits under shade with the aim of slowing down processes that lead to rapid ripening and decay (Rawan et al., 2017). Farmers in Kitui and Taita Taveta counties manually harvested guavas at full ripe stage by use of color and this had great influence on the shelf life of their fruits. Additionally, this harvest stage contributes to high postharvest losses.

Guava postharvest handling practices

Postharvest handling of the guava fruit includes sorting, cleaning, grading, packaging, storage and transportation (Kamsiati, 2016; Sharma, 2019). Postharvest guava storage was not a major practice in both Kitui and Taita Taveta as farmers harvested enough for their consumption. This is explained by the low marketability and consumption of the fruit in Kenya (Chiveu, 2019). After harvesting, the guavas were manually transported to the homestead and market using buckets, sacks, crates or cartons. Such packaging practices are likely to increase mechanical damage of the fruits especially when harvested at full ripe stage (Bakshi, 2015). Most farmers in Kitui and Taita Taveta did not package guavas as the fruit had minimal economic value. Besides, only small quantities were normally harvested for household consumption. Sacks were mainly used for packaging during storage and transportation of the fruits in Kitui. Although the sacks have air spaces that allow for respiration and prevent anaerobiasis (Momin et al., 2018) they should be discouraged as they cause surface injury. In Taita Taveta, farmers opted to use paper boxes to package guava. This was as recommended by (Kaur and Kaur, 2019) that paper boxes were good in ensuring the lowest weight loss, ethylene and respiratory rates, highest soluble solids and vitamin C concentrations in the fruit. However, these packages can expose the fruits to mechanical damages if used for transportation without cushioning the fruits (Singh et al., 2014). Additionally, the fruit is highly perishable and has a delicate skin that is prone to mechanical damage (Gill, 2018). Farmers in Kitui and Taita Taveta counties did not have standard postharvest handling practices for guavas which was a main contributor to huge postharvest losses reported in the two regions.

Guava deterioration

Most of the households harvested small quantities of guava for home consumption and the rest were left to rot in the field which contributed to huge losses. A study conducted by Shivaraj and Patil (2017) in India found that guava losses at harvest and postharvest were approximately 16% increasing the economic losses to guava farmers. Overripe guavas were left to rot in the farm with no alternative use due to low value addition of the crop to shelf stable products such as juices, jams, nectars, wine, animal feeds and in compost making (Kadam et al., 2015). Microbial attacks and mechanical injuries were the major causative factors of the guava losses as reported in Kitui and Taita Taveta. The fruit is highly prone to fruit fly infestation and other pests which reduce shelf life and increase losses (Keith and Zee, 2010). Most respondents (93.8%) reported pests and diseases as the major cause of losses to guavas although they did not use any control measures given that the fruits are neglected and have low commercial value (HCD, 2014) Studies indicate that guavas are highly infested by fruit flies becoming one of the major causes of the fruit loss especially during the rainy seasons (Jatinder, 2017).

Inadequate knowledge on postharvest handling was reported as the second challenge leading to huge losses in Kitui and Taita Taveta and this was attributed to lack of standard postharvest handling procedures affecting harvesting, storage and utilization of the fruit. The significant difference in shelf life of guavas in Kitui (3 days) and Taita Taveta (5 days) is linked to the temperature difference between the counties as Kitui is relatively hotter than Taita Taveta with temperature ranges of 24-34°C and 21-32°C respectively (Cassim and Juma, 2018; Tirra et al., 2019). Higher temperatures result in higher respiration rates that cause rapid fruit deterioration thus resulting in shorter shelf life for fruits in Kitui (Renato et al., 2012). Additionally, guavas have a thin, delicate skin which increases susceptibility to injuries and pest attack resulting in infection that tends to reduce shelf life (Pal, 2009; Singh, 2011). The farmers' strategies of extending guava shelf life by sorting, harvesting small quantities and cool storage have been shown to be effective with other fruits like mango, banana, avocadoes and pawpaw (Kamsiati, 2016). The rate of guava deterioration if influenced by the handling practices preceding storage and the prevailing storage

conditions, this was a major problem in Kitui and Taita Taveta thus huge postharvest losses were recorded.

Storage of guava fruit

Farmers harvested guavas at full ripe stage, which made them highly perishable and prone to mechanical injuries. This is attributed to high respiration rates that increase the ripening process during storage (Rawan et al., 2017). The maturity stage highly influences the storage life of the fruit (Prasad et al., 2020) as it affects its postharvest life by influencing the rate of deterioration. Storage of guavas was not a common practice in both counties which could be linked to lack of knowledge on postharvest handling and storage of guavas. In both counties, farmers did not practice cold storage of guavas which was due to lack of electricity and refrigerators. In the work done by Mitra et al (2012) and Sharma (2019), guavas stored at low temperature (8 to 10°C) had a longer shelf life than those stored at room temperature (20 to 25°C). The strategies put in place to reduce rate of deterioration were sorting of the fruits into unripe, ripe and over ripe and harvesting small quantities. There are other storage methods that were not practiced in Kitui and Taita Taveta but have the potential to extend guava shelf life; use of modified atmosphere storage, individual packaging using cling films, salts (calcium chloride and calcium nitrate) and freeze drying (Adrees et al., 2010; Miano and Jokhio, 2010). Guava shelf life could be extended by combing methods that reduce the rate of processes in the fruit.

Knowledge on hygiene and practices

The clustering of farmers' hygiene and handling knowledge resulted into two major clusters which revealed that guava farmers either had low or relatively high knowledge of hygiene practices. The low knowledge can be linked to the fact that most farmers have low exposure on postharvest handling of the produce (Muhammad et al., 2012). Guava fruit handlers in Kitui had more knowledge on hygienic handling of the fruits which greatly influenced how they handled the fruits after harvest. This could be linked to higher education level of farmers in Kitui than in Taita Taveta. Besides, there was a guava market in Kitui and may have contributed to this as the farmers and guava traders practiced hygienic handling of the fruits to extend shelf life and reduce unnecessary losses from poor handling. A study by Sharif and Obaidat,(2013a) on food hygiene knowledge and practices showed that knowledge scores increased with the levels of education.

Additionally, gender was found to have an influence on knowledge with women tending to be more knowledgeable on handling and hygiene than men, this is attributable to the fact that women had high education level than men (Habib et al., 2019). These results correlate with the findings of Samapundo et al. (2016) that gender significantly influenced knowledge on food safety and hygiene practices where women were found to be more hygienic in handling food than men. Other studies have reported that training on food handling and safety results in increased levels of knowledge (Azmi, 2006). Despite the fact that the respondents from both counties had not received any formal training on postharvest handling of fruits, they displayed somewhat high levels of knowledge which could be influenced by other trainings on food sanitation and food safety. There is therefore need for training of guava handlers on hygiene practices and postharvest handling to reduce losses.

Conclusion

Guava fruit production in Kitui and Taita Taveta is largely subsistent with limited commercialization. Households producing the fruit practiced limited postharvest management to improve the keeping quality of the fruit. However, limited information is available on postharvest handling properties of the fruit. Despite this, the households had acceptable levels of knowledge on postharvest handling of the fruit although there exists a gap in the actual practice and implementation of the knowledge possessed in actual practice. Harvesting of guava was not a common practice as farmers harvested just enough for household consumption and the rest is left to rot in the farms, eaten by birds and animals. This is due to low value addition of the fruit due to its low economic value.

Recommendations

(i) Training farmers on postharvest management of guavas with the aim of increasing its marketability to enhance its production and increase farmer income from the fruit.
(ii) Development of guava postharvest handling standards, guidelines and manuals to be availed to farmers to enhance their postharvest management with aim of averting the huge losses.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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