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Article

# Determinants of Choice of Postharvest Practices in Mango and Passion Fruit Loss Management in Selected Counties of Kenya

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ABSTRACT

Mango and passion fruits are highly perishable and despite the gains in their production, postharvest loss management remain a major challenge. This study therefore sought to identify the determinants of choice of postharvest practices in postharvest loss management of mango and passion fruit in Makueni, Machakos, Embu, Uasin Gishu and Trans-Nzoia Counties. Descriptive cross-sectional design was used on a target population of 18750 smallholder mango and passion fruit households to get a sample size of 402 households through cluster random sampling. The study considered storage location, packaging materials, vehicle transport, store type and cleanliness of the harvest equipment as the postharvest practices. Multivariate probit model was utilised in the analysis of the determinants of the postharvest practices' choices. Age, years of schooling, group membership, access to electricity, access to bank account and internet had a positive and significant effect on the choice of postharvest practices. Gender, access to agricultural training, credit access and off-farm income had a negative significant effect on postharvest practices choices. Increased involvement of men in the postharvest stage lowered the adoption of proper choice of transport and handling of fruit produce by 62%. Agricultural training had a negative and significant effect on the choice of store ($p=0.059<0.1$) and the choice of vehicle transport ($p=0.000<0.01$) for the harvested produce. The multivariate analysis showed that agricultural training accessed is associated with 78.6% decrease of the farmers with proper vehicle transport and 34.1% decrease on store type utilized for harvested produce. The model showed that 88.7% of the farmers accessed credit for other farming needs other than postharvest loss management. The findings show that agricultural training offered focuses more on increasing production and farmers channel more of their income and credit to production and very little to postharvest management. It is recommended that National and County Departments offering agricultural training to mango and passion fruit farmers should emphasize not only on fruit production practices but also on postharvest loss management. Farmers need also to invest not only on increasing fruit production but also on postharvest management.

**Keywords:** *Postharvest practice; determinants; mango; passion fruit; postharvest loss; management*

## 1. Introduction

Fruit farming greatly contributes to the world's food security, income generation, employment creation and provision of raw materials to manufacturing industries (Dejenie & Kakiso, 2023). Mango (*Mangifera indica*) is a member of the Anacardiaceae family and is grown commercially in over 90 countries worldwide both in the subtropical and tropical regions, where India is the leading producer (Mujuka *et al*., 2020; García-Mahecha *et al*., 2023). Mango yields the greatest production worldwide of above 50% of all major tropical fruits (Zakaria, 2021). Global mango production is predicted to be 21.5 million



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metric tons yearly, with a 2.6% annual growth rate (Musyoka, 2020). Mango is among the most widely consumed fresh fruits in the world. Continued expansion of mango cultivation area has driven sustained annual yield increases such that mango are now among the five largest fruits in the world (Wang et al., 2023).

Kenya is one of Africa's main mango growers, with Makueni, Machakos, and Embu Counties leading with over 42,000 hectares of mango cultivation (Muriithi *et al*., 2020; Musyoka, 2020). In Kenya, mango is the next most valued fruit after banana contributing about 19.4% of all fruit exports (Wangithi *et al.,* 2021). Mango farming generates around 5% of Kenya's Agricultural Gross Domestic Product (GDP) and around 2% of the Nation's GDP and employs a large number of casual workers (MOALF, 2020). Mango is grown in large quantities each year, with over 98% consumed locally and only 1-2% exported (FAO, 2020). However, between the time of harvesting and the time of delivery to consumers, 40-50% of mango is wasted in Kenya and globally 25-40% loss is reported (Mujuka *et al.,* 2020; Parvin *et al*., 2023).

Passion fruit (*Passiflora edulis*) is widely grown in many parts of southern China as an edible tropical fruit with excellent nutritional value and high economic value (Li *et al.,* 2022). In 2021, postharvest fruit rot was observed on 20 to 25% of passion fruit in several fruit markets increasing the magnitude of postharvest loss (Li *et al*., 2022). Passion fruit is a minor tropical fruit whose commercialization started in Uganda and then Kenya. Passion fruit is the Kenya's third most significant fruit crop, cultivated for both domestic and export markets (Chepkoech *et al*., 2020). Passion fruit is currently consumed fresh in enormous quantities, locally manufactured into juices and flavors, and a minor fraction is shipped fresh to European markets (Mamo, 2021). Production areas for passion fruit in Kenya include among others Central Kenya and North Rift region of Trans Nzoia, Uasin Gishu and Nandi Counties involving smallholder farmers (Chepkoech *et al*., 2020). In Kenya, the crop has a lot of commercial potential because demand for both fresh fruit and processed juice is increasing, and export markets are developing (Asande *et al*., 2020).

As a result, the enterprise offers a speedy path to poverty alleviation, job development, and increased food security. However, insufficient input application and administrative capacity among smallholder farmers provide a challenge to achieving production efficiency (Azizi, 2020). Kenya exports a lot of raw purple passion fruit to Europe, particularly to the United Kingdom, Holland, France, Germany, and Belgium (Smith *et al*., 2018; Mamo, 2021). In addition, the export trend has not been stable over the years due to unreliable production, high postharvest losses and stringent market requirements. Over 50% of passion fruit loss is reported in every harvesting season in Kenya (Ambuko, 2017).

Postharvest practices that are performed on fresh items including harvesting, cleaning, grading, packaging, cooling, storage, transport and handling have a significant influence on management of postharvest losses (Kaur *et al*., 2021). Fruit farming is an enterprise that majority of smallholder households engage in as a source of livelihood (Ajwang, 2019) though most fruits are characterized by high perishability which if not properly managed fruit loss may be a major problem. Mango and passion fruit farming forms among one of the lucrative enterprises in the areas they are grown and marketed. However, cultivation of mango and passion fruit faces numerous problems, including seasonal volatility in production throughout time and inadequate knowledge on value addition and postharvest management (Rajapaksha *et al.,* 2021). Furthermore, the poor postharvest management leads to huge quantities being lost during the peak season (Gebre *et al*., 2021). Mango are highly perishable therefore necessitating careful control of packaging, transportation and distribution (Materechera & Scholes, 2022).

In Kenya, farmers continue to experience postharvest losses of fruits especially during seasons of surplus production. Mango is prone to high perishability and has high propensity for several postharvest pathogens. Additionally, mango are climacteric fruits and ripen very quickly leaving them delicate and vulnerable to attack by a variety of pathogens (Hasan *et al.,* 2022). These related issues ultimately have an impact on the worldwide mango production by further limiting their ability to be handled, stored, and transported over great distances for consumption and marketing leading to postharvest losses (Parvin et al., 2022). These losses reduce the fruits available for local consumption and market and leads to loss of income (Opara *et al*., 2021).

Reducing postharvest losses through use of better postharvest choices could lead to food security for the growing population, food health and safety as well as improved quality (Kaur *et al.*, 2021). There has been little focus on the postharvest management which has contributed to increase in postharvest losses and low earnings by the smallholder farmers. Several studies among them Musyoka (2020) have focused on mango and passion fruit value addition strategies but limited knowledge exists on the low uptake of proper postharvest technologies. Given the inflexibility of available resources, attention should now turn to postharvest losses in Kenya's fruit subsector, which are reported to be as high as 50% (Mujuka et al., 2020).

The farmers' socioeconomic factors may influence such conditions as the location and type of store used by the farmers, cleanliness of the harvesting equipment, type of vehicle transport as well as appropriateness of the packing materials for mango and passion fruit. In Kenya for instance most vehicles transporting fruits to the markets are unrefrigerated and therefore the increased temperatures result to more deterioration of the fruits (Amwoka, 2021). This study, therefore, aimed at identifying determinants of postharvest practice choices for mango and passion fruit loss management in Machakos, Makueni, Embu, Uasin Gishu and Trans Nzoia Counties.

## 2. Methodology of the Study

### *2.1. Description of the Study Area*

The study was conducted in Makueni, Machakos and Embu Counties located in the Eastern region as well as Uasin Gishu and Trans Nzoia Counties in the Rift valley region of Kenya. The Eastern region is characterized with warm climate and semi-arid areas with an annual precipitation of 500 to 700 millimetres (mm) (Ndungwa, 2021). The climatic conditions in the Eastern region are fit for mango farming and thus Makueni, Machakos and Embu Counties were suitable for the study. Trans Nzoia County located in the Rift Valley region is characterized by moderate temperatures with a rainfall of 760 mm per year (Wanjiru, 2016). Uasin Gishu is located in the Rift Valley region characterised with warm to hot temperate conditions and an average rainfall of about 900 to 1100 millimetres (Gichuru *et al.,* 2019). The North Rift Valley's agriculture sector is supported by the Mau Escarpment's steady rainfall and fertile soils. Trans Nzoia and Uasin Gishu Counties forms among the Counties located in North Rift Valley region with the main economic activities being crop farming including maize and passion fruit production and livestock rearing (Boit, 2019) making it fit for the study.

### *2.2. Research Design and Sampling*

A descriptive cross-sectional design was used in this study. Cross-sectional survey was found appropriate in covering the selected Counties of Kenya. The design was appropriate in identifying the determinants of postharvest practices choices on mango and passion fruit postharvest loss management. This study concentrated on smallholder households involved in mango and passion fruit farming located in Machakos, Makueni, Embu, Uasin Gishu and Trans Nzoia Counties. The study used a target population of 18750 smallholder households to obtain a sample representing farmers in mango and passion fruit farming in these areas. This secondary data was sourced from Horticultural Crops Directorate report (HCD, 2020). Kothari (2004) sampling formula was utilized to compute the desired sample size for the study. The sample size of smallholder households was calculated as follows.

$$n = \frac{N}{1+N(e^2)} = \frac{18750}{1+18750(0.05^2)} = 392 \dots\dots\dots (1)$$

Where,

n= desired sample size

N=population size

e = acceptable error.

Since the study covered a large population, 10 respondents were added to 392 obtained above to cater for non-responses, forming a sample size of 402 smallholder households. The sample size assumed 95% confidence interval and an acceptance error of 5%.

### *2.3. Sampling Procedure*

The sample size of 402 smallholder households was distributed proportionately to the selected Counties based on the estimated number of smallholder households per County as given in Table 1. The study employed cluster random sampling technique. First, purposive sampling technique was employed to choose the five Counties; Machakos, Makueni, Embu, Uasin Gishu and Trans Nzoia, since they are the major mango and passion fruit growing areas in the Eastern and North Rift regions of Kenya, respectively. In the second stage, the Counties were clustered heterogeneously with respect to

theSub-Counties. In the third stage, the Sub-Counties to be included in the study were selected at random from each County. Lastly, from the selected Sub-Counties, a list of smallholder mango and passion fruit households was generated with the help of the Ministry of Agriculture Extension staff to help in selecting respondents for the study through a simple random sampling method. The sample size distribution formula to get the number of respondents per County was as follows.

$$\frac{No.household\ \ in\ fruit\ farming}{Target\ population} \times \text{sample} \ldots\ldots\ldots (2)$$

| County | Number of smallholder households | Sample size |
|---|---|---|
| Makueni | 6500 | 139 |
| Machakos | 4000 | 86 |
| Embu | 2250 | 48 |
| Uasin Gishu | 4000 | 86 |
| Trans Nzoia | 2000 | 43 |
| | 18750 | 402 |

### *2.4. Data Collection and Analysis Method*

A semi-structured questionnaire was used in collecting primary data. Academic supervisors and stakeholders in the horticultural sector helped in the validation of the questionnaire. For questions on scale basis the study employed Cronbach alpha coefficient. The scale reliability coefficient was 0.7003 which as per the rule of the thumb by George and Mallery (2018), is acceptable and therefore the questionnaire was reliable for use. The questionnaire was administered to respondents selected at random from the study area in a face-to-face interview method in order to obtain data on the determinants of choice of postharvest practices that have an effect on the postharvest loss management of mango and passion fruits. Mango related data was obtained from three counties including Makueni, Machakos and Embu County due to their high production of the fruit. Passion fruit related data was taken from Trans Nzoia and Uasin Gishu Counties to act as a representative of the other passion fruit producing areas in Kenya. The study engaged four enumerators in each of the selected study areas. Respondents included heads of mango and passion fruit producing households selected in the study area. The data gathered was coded and categorized. Data entry was done on Microsoft Excel 2019 software while analysis was done on SPSS 28 and STATA 17 software. Econometric analysis using multivariate Probit model was used on data obtained to address the study objective.

### *2.5. Multivariate Probit Model Specification*

Postharvest practices are numerous and can range from harvesting, cleaning, grading, handling, packaging, as well as storage (Rajapaksha *et al.,* 2021). Multivariate Probit was found suitable in analysing the determinants of the choice of post-harvest practices since it allows for complementarity and supple mentality of choices and takes into consideration errors correlation for the different alternative choices. Following Cappellari & Jenkins (2003) the multivariate probit model is represented as follows.

$$Y_m^* = \beta_m X_m + E_m \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where:

$E_m$ are error terms with a multivariate normal distribution, having each a zero mean and a unit variance.

$Y_m$ is the binary outcome of the choice of postharvest practice.

$X_m$are the independent variables.

$\beta_m$ are parameters to be estimated.

$$Y_m = 1 \text{ if } Y_m^* > 0\ and =\ 0\ otherwise.. (4)$$

That is;

$$Y_1 = \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + E$$
$$\vdots \qquad \vdots \qquad \vdots \qquad \vdots^{1}$$
$$Y_m = \beta_1 X_{1m} + \beta_2 X_{2m} + \cdots + \beta_{nm} X_{nm} + E_m$$

where;

$Y_1 \ldots Y_m$=1 if the farmer stores the fruit produce in a suitable location away from foreign materials or otherwise not, if the farmer ensures hygienic and clean packing strategies of the fruit otherwise not, if the farmer uses clean harvesting equipment and ensures cleanliness of the fruits or otherwise not, if the farmer has access to proper transport and

Table1: Postharvest practices variable description

| Variable | Variable description | Measurement | Expected outcome of cleaning, packing, handling and storage |
|---|---|---|---|
| Age | Age of the farmer | Years | +/− |
| Credit | Access to credit (1=yes, 0=no) | Dummy | +/− |
| Education | Years in school | Years | +/− |
| Experience | Experience of the farmer | Years | +/− |
| Farm size | Fruit production area | Acres | +/− |
| Gender | Male=1 | Dummy | +/− |
| | Female =2 | | |
| Household off farm Income | Monthly household off farm income | Ksh | +/− |
| Bank account | Access to bank account (1=yes, 0=no) | Dummy | +/− |
| Group membership | Access to group membership (1=yes, 0=no) | Dummy | +/ |
| Training | Access to training (1=yes, 0=no) | Dummy | +/− |
| Market access | Distance travelled to the market | Kilometres | +/− |
| Electricity | Access to electricity (1=yes, 0=no) | Dummy | +/− |

Source: Author's compilation from reviewed literature

does proper loading and handling of fruits or otherwise not, if the farmer has access to properly cooled stores otherwise not. $E_m$ are error terms that follows a multivariate normal distribution having a zero mean each and a unit variance. $Y_m$ is the binary outcome of the choice of postharvest practice. $X_m$ are the independent variables shown in Table 2. $\beta_m$ are parameters to be estimated.

## 3. Results and discussion

### *3.1. Descriptive statistics of determinants of Mango postharvest loss management*

The study found that most of the respondents had an average age of 50.5 (±11.88) years. The study involved smallholder mango farmers and relied on the household's head. The average years of schooling for the respondents in the study was 9 years (±4.6). The results as provided in Table 3 varied significantly across the Counties (F=329.35; p=0.0000) with respondents in Embu and Makueni having more years of schooling as opposed to their counterparts in Machakos. The study found that the average size of land operated by the smallholder mango farmers in the three Counties was 7.5 hectares (±5.6). On average the respondents in the study areas have to travel a distance of 3.27 kilometers to reach the nearest market. Makueni County registered the highest mean (4.33±3.69) of the market distance that the smallholder mango farmers have to travel to reach the market (Table 3). Ninety percent (90.07%) of respondents were males and 9.93% were females which may imply majority of the household heads were males (Table 3).

Table2: Descriptive Statistics of Continuous variables and Gender of Mango Postharvest Loss Management

| Variable | Makueni | Machakos | Embu | Average | F value | Prob >F |
|---|---|---|---|---|---|---|
| Age | 50.61 (12.54*) | 49.47 (12.12) | 52.44 (9.13) | 50.57 (11.88) | 0.97 | 0.38 |
| Years of schooling | 10.14 (2.88) | 3.55 (1.75) | 14.27 (2.36) | 8.79 (4.6) | 329.35 | 0.00 |
| Land area operated | 9.76 (5.64*) | 4.57 (3.74) | 6.30 (5.47) | 7.51 (5.59) | 29.28 | 0.00 |
| Market distance | 4.33 (3.69*) | 1.94 (1.40) | 2.63 (1.36) | 3.27 (3.01) | 20.76 | 0.00 |
| | | | | | Pearson chi2 | Pr |
| Gender | | | | | 11.00 | 0.00 |
| Male | 92.75 | 93.02 | 77.08 | 90.07 | | |
| Female | 7.25 | 6.98 | 22.92 | 9.93 | | |

*Figures in the () indicate the standard deviation associated with the mean

Table3: Descriptive Statistics of Categorical variables of Mango Postharvest Loss Management

| Variable | Makueni | Machakos | Embu | Overall Percentage |
|---|---|---|---|---|
| Use of producer group | 23.91 | 4.65 | 0 | 13.6 |
| Membership to an organization | 65.94 | 33.72 | 0 | 44.12 |
| Access to credit | 5.8 | 11.63 | 4.17 | 7.35 |
| Access to training | 50.72 | 36.05 | 54.17 | 46.69 |

The findings of this study found that, majority of the smallholder mango farmers lacked adequate access to credit services that would aid their farming. In addition, only 13.6% of the farmers used producer marketing groups to sell their produce with a half (50%) having access to training on fruit production and membership to a farmer organization (Table 4).

### *3.2. Descriptive statistics of determinants of passion fruit loss management*

The findings of the study revealed that the mean age of the smallholder passion farmers was roughly 44 (±9.23) years of age for both Uasin Gishu and Trans Nzoia Counties (Table 5). The study involved the household heads who practiced passion fruit farming. The average years of schooling for most of the respondents was 12 (±3.04) years implying most farmers had attained primary level of education and were in between secondary and tertiary levels of education (Table 5). The average size of land operated by the respondents was 6.4 (±5.37) hectares with Uasin Gishu farmers operating in large farm size of 6.97 (±6.0) than farmers in Trans Nzoia County who were operating a farm size of 5.3 (±3.65) hectares.

The study findings revealed that the smallholder passion farmers in Uasin Gishu and Trans Nzoia Counties could travel a mean distance of 4.33 (±0.23) kilometers to reach the nearest market. The farmers in Uasin Gishu County could travel 4.5 (±0.24) Kilometers to reach the market which is a far distance compared to the one travelled by the passion fruit farmers in Trans Nzoia County of 4.02 (±0.47) kilometers to the nearest market. In this study about 90% of passion fruit farmers were males while only 10% were females. The study established that farmers who were in producer groups were 19.7% with those who were members to a farmer-based organization were 12.12%. In

addition, only 4.55% of the respondents could access credit. Most of the passion fruit farmers (68%) had also access to agricultural training (Table 6).

Table 4: Descriptive Statistics of Continuous variables and Gender of Passion Fruit Postharvest Loss Management

| Variable | Uasin Gishu | Trans Nzoia | Average | T-Value | Prob >t |
|---|---|---|---|---|---|
| Age | 43.91 (10.23*) | 44 (7.09) | 43.94 (9.23) | -0.06 | 0.52 |
| Years of schooling | 13.40 (2.31) | 9.82 (2.91) | 12.17 (3.04) | 7.67 | 0 |
| Land area operated | 6.97 (6.0*) | 5.3 (3.65) | 6.4 (5.37) | 1.67 | 0.05 |
| Market distance | 4.5 (0.24*) | 4.02 (0.47) | 4.33 (0.23) | 0.159 | 0.00 |
| | | | Overall Percentage | Pearson chi2 | Pr |
| Gender | | | | 7.51 | 0.01 |
| Male | 95.35 | 80.43 | 90.15 | | |
| Female | 4.65 | 19.57 | 9.85 | | |

*Figures in the () indicate the standard deviation associated with the mean

Table 5: Descriptive Statistics of Continuous variables and Gender of Passion Fruit Postharvest Loss Management

| Variable | Uasin Gishu | Trans Nzoia | Overall Percentage | Pearson Chi2 | Pr |
|---|---|---|---|---|---|
| Use of producer group | 0.00 | 56.52 | 19.70 | 60.53 | 0.00 |
| Membership to an organization | 3.49 | 28.26 | 12.12 | 17.27 | 0.00 |
| Access to credit | 3.49 | 6.52 | 4.55 | 0.64 | 0.43 |
| Access to training | 82.56 | 41.30 | 68.18 | 23.51 | 0.00 |

### *3.3. Multivariate Probit Estimates for Choice of Postharvest Practices Available to Mango and Passion Fruit Farmers in the Five Counties*

Multivariate Probit (MVP) model was used to analyze determinants of farmers' postharvest choices. The MVP model generated a covariance matrix of the regression equations between the postharvest practices' choices using the joint estimation approach as shown in Table 7. The likelihood ratio test [(LR $\chi^2$ (10) = 187.184 (Prob > $\chi^2$ = 0.0000)] of the null hypothesis that the covariance of the error terms across equations are not correlated was rejected. The results in Table 7 reveal that the estimates of the coefficients were statistically significant (P<0.001) for the 10 pairs of the postharvest choices. The sign for the coefficients was positive indicating that the model was suitable for the study and that there was interdependence

of the choices. In this case, different postharvest practices employed by the farmers complements each other. This complementarity infers that a change in policy that affects one postharvest practice is likely to have spillover effects on other Postharvest practices.

The results showed in Table 8 shows the multivariate probit estimates obtained through the maximum likelihood method. The multivariate analysis showed that the Wald test (65) ($\chi^2$ = 388.64, ρ = 0.00) had a significant level of 1%, indicating that the model coefficients are significant and that the explanatory power of all the factors involved in the model are satisfactory. Therefore, the multivariate probit model fits the study in a reasonable way.

The findings of the multivariate probit model showed that there exists a positive and significant relationship (p=0.004<0.01) between age and choice of vehicle transport. Increase in age meant that the farmers opted to advance in the use of cleaned, properly packed and maintained vehicles free from the risks of postharvest loss in transportation of mango and passion fruits. The findings concur with those of Wangithi *et al*. (2021) who established that older farmer had more farming experience and knowhow of the benefits of adopting modern technologies to prevent against any loss. Age also had a positive and significant effect (p=0.002 <0.01) on the type of store utilized by the farmers for storing mango and passion fruit after harvesting. The findings reveal that farmers use of closed and cold stores increased by 2.5% with the increase in age (Table 8). This may imply that as the fruit farmers got older, they had accumulated enough resources, skills and experience to facilitate shift from using roadsides and fields for storage to using closed and cold stores. The results are in line with those of Wangithi *et al.* (2021) who established that as the farmers' age increased it implied farmers had gotten more resources and could invest in loss management practices to mitigate postharvest loss.

Years of schooling had a positive and significant effect (p<0.01) on all the choices of postharvest practices adopted by the farmers. This may imply that, as the farmers get more education, they become more knowledgeable on the various postharvest practices they can adopt to minimize postharvest loss. Farmers therefore, diversify and adapt different postharvest choices since they have knowledge on them. The findings concur with those of Kabir *et al.* (2023) who found out that education level contributes positively to postharvest loss management. Spending more years in school increased the farmer's intellect thus being able to integrate postharvest practices that were effective towards postharvest loss management.

Gender had a negative and significant effect (p=0.001<0.01) on choice of packing materials used by the farmers. These findings imply that being male decreased the probability of using proper pack materials among the smallholder mango and passion fruit farmers. Additionally, gender had a negative and significant effect (p=0.025<0.05) on the type and conditions of vehicle transport.

The more the number of men involved in the postharvest management the lesser the adoption of proper postharvest technologies during transportation. Increase in the number of men involved in postharvest management by one lowered the probability for the choice of using properly maintained and temperate controlled vehicles by 62%. However, these results contradict those of Misango *et al*. (2022) who found that being male increased the adoption of proper postharvest technologies as opposed to what was adopted by the women. In Misango *et al.* (2022) study, gender was positive and had a significant effect (p<0.05) on postharvest loss management.

Agricultural training accessed had a negative significant effect (p=0.000<0.01) on the choice of vehicles used for transport of the produce. In addition, agricultural training had a negative and significant effect (p=0.059<0.1) on the choice of store type utilized by mango and passion fruit farmers. The findings reveal that the training accessed didn't help in postharvest loss management since there was 34.1% decrease in the choice of cold rooms and closed stores use. This meant that the farmers continued to use open and field stores which increased the risk of postharvest loss of their fruits. The MVP model results revealed that 78.6% of the farmers didn't improve on cleanliness and maintenance of the stores even after receiving the training (Table 8).

Table 6: Correlation coefficients for MVP regression equations

| | Store location | Proper packing | Vehicle transport | Store type | Harvest equipment cleanliness |
|---|---|---|---|---|---|
| Store location | 1.00 | | | | |
| Proper packing | 0.483(0.125) *** | 1.00 | | | |
| Vehicle transport | 0.551(0.109) *** | 0.642(0.146) *** | 1.00 | | |
| Store type | 0.446(0.105) *** | 0.387(0.118) *** | 0.604(0.105) *** | 1.00 | |
| Harvest equipment cleanliness | 0.532(0.123) *** | 0.962(0.146) *** | 0.699(0.128) *** | 0.554(0.118) *** | 1.00 |

This exposed the produce to more postharvest loss. According to mango and passion fruits farmers, the agricultural training offered was more on the production of the fruits and less on the postharvest loss management. Most farmers recorded increased production but were unaware of the postharvest practices to use to mitigate loss. The findings contradict those of Oyedokun *et al*. (2023) who found out that increased facilitation of extension agents to offer agricultural training impacted several farmers to increase in capacity of managing postharvest loss.

Credit access had a negative and significant effect ($p=0.012<0.05$) on packing materials utilized by the farmers. The findings reveal that 88.7% of the farmers utilized credit for other purposes such as expanding their farm production other than acquiring proper packing materials that are clean and hygienic to prevent postharvest loss of mango and passion fruit produce. This therefore, increased the risk of exposure of their produce to postharvest loss. The findings concur with those of Mensah *et al*. (2021) which reported that most farmers who accessed credit did not channel it to postharvest loss management but used it in expansion of other enterprises.

Access to bank account had a positive and significant effect ($p=0.027<0.05$) on the location of the store used by the farmers for their mango and passion fruit produce. The findings reveal that as the number of mango and passion fruit farmers who had access to bank account increased by one, the tendency to install stores that were safe and away from other material also increased by 39% (Table 8). Typically, access to bank accounts may imply that the farmers were earning or had some income that they utilized to set up closed stores that were not open and were free from other foreign materials that would result to postharvest loss. The findings concur with those of Akpa et al. (2022) that established that financial inclusion in deployment of postharvest practices led to positive and significant effect in reducing postharvest losses. Farmers who had access to bank accounts were more likely to adopt postharvest technologies effective in minimizing the loss.

Membership to a cooperative or a farmer-based organization (FBO) had a positive and significant effect on all the choices of practices available for the postharvest loss management of the mango and passion fruit produce. For instance, in this study being a member of any group increased the probability that the farmers used proper packing materials that were cleaned and maintained and free from contamination by 51.2% (Table 8). A strong probable explanation would be that belonging to a group helped farmers learn and appreciate the importance of fruit postharvest management. Farmers in groups easily received training on postharvest loss management where they exchange and generate new ideas. The findings are consistent with those of Kabir *et al.* (2023) who observed that belonging to a group increased the likelihood of farmers participating in postharvest activities of mango fruits.

Table 7: Multivariate Probit Estimates for Choice of Postharvest Practices Available to Mango and Passion Fruit Farmers in the Five Counties

| Predictors | Storage away from foreign materials | Proper Packing materials use | Transport and handling condition of the vehicle | Storage type utilized | Cleanliness of harvesting equipment |
|---|---|---|---|---|---|
| | Coefficient | Coefficient | Coefficient | Coefficient | Coefficient |
| Age | 0.01 (0.008) | 0.010(0.01) | 0.023(0.008)*** | 0.025(0.008)*** | 0.010(0.009) |
| Years of schooling | 0.075(0.027)*** | 0.144(0.032)*** | 0.081(0.03)*** | 0.085(0.029)*** | 0.137(0.030)*** |
| Gender | 0.303(0.297) | -1.00(0.293)*** | -0.620(0.277)** | -0.350(0.282) | -0.39(0.290) |
| Fruit production area | -0.009(0.008) | -0.001(0.01) | -0.008(0.007) | -0.009(0.008) | 0.021(0.024) |
| Training access | -0.05(0.172) | 0.006(0.206) | -0.786(0.189)*** | -0.341(0.180)* | -0.051(0.193) |
| Credit access | 0.269(0.369) | -0.887(0.353)** | 0.492(0.356) | 0.151(0.348) | -0.398(0.361) |
| Bank account access | 0.390(0.177)** | -0.063(0.212) | 0.251(0.184) | -0.179(0.1810 | -0.093(0.203) |
| Cooperative membership | 0.525(0.201)*** | 0.512(0.243)** | 1.264(0.212)*** | 1.507(0.218)*** | 0.58(0.242)** |
| Off farm income | -1.303(0.217)*** | -1.443(0.263)*** | -1.063(0.256)** | -1.189(0.245)*** | -1.322(0.255)*** |
| Market distance | -0.012(0.03) | 0.055(0.036) | 0.030(0.037) | -0.010(0.029) | -0.001(0.033) |
| Electricity access | 0.057(0.181) | 0.511(0.214)** | 0.470(0.179)*** | 0.544(0.179)*** | 0.514(0.205)** |
| Number of observations | | | 400 | | |
| Log likelihood | | | -636.287 | | |
| Wald Chi2(65) | | | 388.64 | | |
| Prob>chi2 | | | 0.000 | | |

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

In another instance, cooperative or FBO membership had a positive and significant effect ($p=0.000<0.01$) on the choice of fruits store used by the farmers. The membership to any group implied that the farmers had increased access to closed stores and cooled stores. During the study it was also observed that membership to the FBO or the cooperative implied that the farmers received education on the safety of installing closed store as well as material support in form of construction materials to set up closed stores free from possible contaminants that would cause postharvest loss of their fruit produce.

The results concur with those of Kabir *et al*., (2023) and Musyoka *et al.* (2020) who revealed that group membership was significant and had a positive relationship to the adoption of different postharvest technologies including cold stores as well as produce handling techniques. Similarly, being a member to a certain farmer group be it a cooperative or an FBO yielded a positive and significant effect ($p=0.017<0.05$) on the choice of using clean and hygienic harvesting equipment. The membership to the group ensured there was 58% increase in the use of clean and properly maintained containers, equipment and tools for harvesting free from contamination (Table 8). The farmers could enlighten each other on the need to ensure sustained hygiene of the harvesting equipment amongst group members.

The results contradict those of Mwungu *et al.* (2020), who claimed that belonging to a farmer group reduced the likelihood of adopting appropriate postharvest techniques. This was surprising because social networking was thought to be a way of getting fresh knowledge and thus boosting the chances of being exposed to innovative farming ideas. The level of farmers off-farm income had a negative and significant effect ($p=0.000<0.01$) for all the choices of postharvest practices employed in loss management. This implies that as farmers' off-farm income increases the level of adoption and use of proper postharvest practices decreases which may result to high postharvest loss. The findings also may imply the off-farm income was diverted to other uses other than seeking to implement postharvest practices to manage postharvest loss.

The findings contradict those of Ainembabazi (2021) who established that off farm income had a positive and significant effect on the adoption of postharvest practices for management of postharvest loss. The findings of Ainembabazi (2021) implied that as farmers' off-farm income increased the more the farmers got the capacity to install technologies for management of postharvest loss. Access to electricity had a positive significant effect for the choice of packing materials ($p=0.017<0.05$) used and the choice of vehicle transport ($p=0.009<0.01$) utilized. This implied that having access to electricity improved the farmers' use of proper packing materials (51%) that may reduce possible postharvest loss.

In addition, the access to electricity had a positive and significant effect on the type of store used ($p=0.002<0.01$) and the cleanliness of the harvesting equipment ($p=0.012<0.05$). This implied that access to electricity assisted farmers in the adoption of cold stores (54%) most of which are dependent on the electricity for operation and are more effective in postharvest storage of the produce (Table 8). The findings are in line with Mujuka *et al.* (2021) who reported that investing in technologies such as use of electricity in postharvest management had a significant effect towards reducing loss. According to Mujuka *et al*. (2021) such investment enabled use of cold rooms that were more efficient in postharvest loss reduction.

## 4. Conclusion and Recommendation

The choice of postharvest practices that mango and passion fruit farmers adopt to mitigate fruit loss is determined by the age and the education level of the farmer. Educated and aged fruit farmers are much better in adopting proper postharvest practices towards loss management. Farmers in FBOs or cooperatives have access and more knowledge on better postharvest practices choices because of social networking that help in reducing fruit loss. Availability of electricity access helped in installation of postharvest technologies that are power controlled and appropriate to minimizing postharvest loss. Increased involvement of the men in postharvest management practices decreased the capacity to manage loss among mango and passion fruit farmers.

Mango and passion fruit farmers encounter postharvest loss since agricultural training offered relies mostly on fruit production

practices and little on the best choices of postharvest loss management. It was also observed that farmers had no prospects of investing in postharvest technologies and channeled much of their off-farm income into other farm operations such as crop production needs. Both National and County Departments of agriculture need to offer holistic training to mango and passion fruit farmers, and should emphasize not only on fruit production practices but also more on postharvest loss management. Smallholder mango and passion fruit farmers are encouraged to not only invest their off-farm income and credit accessed in production but also in the installation of proper postharvest technologies.

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**Conflicts of Interest**

The authors of this manuscript declare no conflict of interest.

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