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Utilization of Post-Harvest Technologies for Improved Food Security: Case of Maize and Mangoes among Smallholder Farmers in Kerio Valley Elgeyo Marakwet County, Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. Author LC designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors WA and DB managed data analysis and reviewed the draft manuscript, authors VKM and AOO contributed to data analysis and revision of the final manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Limited availability of improved post-harvest technologies or inappropriate use of available technologies leads to spoilage of food resulting to post-harvest losses. The losses contribute to food insecurity in the sense that availability and accessibility of food will be limited. Adoption of post-harvest harvest technologies boosts the agricultural sector, and has been seen as a pathway out of poverty and food insecurity. The study assessed the utilization of post-harvest technologies

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among smallholder farmers in Kerio Valley Elgeyo Marakwet County, Kenya and their correlation to food security. The main objective of the study was to determine factors that influenced adoption of post-harvest technologies for both maize and mango among the farmers. A cross sectional survey was used to collect data using self-administered questionnaire and interview schedules on 217 respondents. There was a significant relationship between gender (r- .264, *P*<0.001), age(r=.350, *P*<.05), education level(r=.956, *P*<.001), income(r=656, *P*<.001) and extension services(r=.907, *P*<.001) and adoption of post-harvest technologies. Adoption and use of improved post-harvest and processing technologies need to be promoted to curb post-harvest losses thus improving food security. In addition, there is need for intense extension services on post-harvest technologies to enhance awareness and adoption.

Keywords: Adoption; agricultural technology; post-harvest losses.

1. INTRODUCTION

There are significant post-harvest and agro-processing losses in the rural farming communities in many parts of Kenya. The losses are mainly attributed to the limited availability of efficient technologies or poor utilization of the technologies that are available [1, 2].

This study focused on post-harvest technologies of mangoes and maize. For the case of mangoes, losses can be as high as up to 50% of the harvested fruits [3]. This is because mango processing in most parts of Kenya has not been taken into consideration and thus limited investment in agro processing and value addition [4]. Post-harvest technologies used during handling can either maintain or deteriorate the quality of the commodity [3]. For instance during harvesting of mangoes majority of farmers use harvesting methods such as climbing of mango trees, using poles and shaking of trees which exposes the fruits to more mechanical damages [5]. Storage facilities of mangoes is limited and in some parts of Kenya it is virtually nonexistent. This therefore has led to most farmers (63%) not storing their fruits simply because of lack of cold storage [5, 6]. The harvested mangoes are basically kept in shades as the farmers wait for buyers to transport the produce to the market [6]. Packaging materials used also contribute to post-harvest losses, because most of the farmers use gunny bags and sucks as packaging materials instead of plastic crates and during the process of transit, losses are experienced due to bruises and compression [3]. One of the strategies to reduce post-harvest losses is to optimize handling of the product at all stages [7]. This could be achieved by embracing and utilizing post-harvest technologies available [8]. Agricultural technologies such as simple fruit harvesting tool which has a bag attached to it has been found to be more effective than other alternatives because it prevents the fruit from falling. In addition, processing should be done to utilize surplus fruits especially during the peak period [9].

Losses during post-harvest handling of maize are estimated to about 25% of the total crop harvested and these losses are associated to poor storage facilities, poor handling and limited agro-processing [10]. Traditional storage structures predisposes the commodity to various damages since it cannot maintain the quality of the produce for a long period of time [11]. Majority of farmers use traditional granaries and living rooms to store their produce [12, 13]. Processing activities are normally the frequently used methods such as milling and sun drying [14]. Use of metal silos and purdue bags reduces losses during storage compared to polypropylene bags [3]. Further processing such as milling and fortification are also essential as a remedy of curbing post-harvest losses [15]. Food loss and wastage can be minimized through greater investments, and wider adoption of improved post-harvest and agro-processing technologies. Adoption of these technologies and improving management practices can be a game changer in terms of national and global food security [16]. The current situation on post-harvest losses and the technologies used necessitated the need of farmers to be exposed to improved post-harvest technologies of crops under study. The objective of this study therefore aimed at determining the socio-economic and institutional factors that influence adoption of these technologies. The information obtained would be important in providing strategies that should be put in place to improve the socio economic status of farmers thus increasing the rate of adoption.

2. METHODOLOGY

2.1 Study Area

The study was conducted in Kerio Valley in Elgeyo Marakwet County which covers a total area of 3029.9 km^2. The County extends from latitude 0^o 20′ to 1^o 30′ to the North and longitude 35^o 0′ to 35^o 45′ to the East. It borders West Pokot County to the North, Baringo County to the East, Trans Nzoia County to the Northwest and Uasin Gishu County to the West. It has an elongated shape and is wedged in between the Uasin Gishu Plateau on the West and the Kerio River on the East. The Kerio River has its source in the Southern highlands of the County and drains into Lake Turkana in the North [17].

The county is divided into three topographic zones: the Highlands, the Kerio Valley and the Escarpment. In Kerio Valley where the study was carried, the altitude is between 900m to 1000m above the sea level. The temperatures can be as high as 30°C during the dry season and as low as 17°C during the rainy season. The rainfall ranges between 850mm to 1000mm per annum thus the area along the Valley being semi-arid but with high production potential because of fertile soils. Agriculture is the main economic activity and a key source of livelihood for the people [18].

2.2 Study Design

The study adopted cross sectional survey research design with components of action research. The design was suitable for the study since it provided information on socio-economic and institutional factors that influenced adoption of post- harvest technologies.

2.3 Target population and Sample Size

The target population of the study comprised of 719 registered mango farmers who were also growing maize from Tambach, Soy and Arror wards in Kerio Valley. A total sample size of 217 respondents were randomly selected from three wards of the selected sub-counties.

2.4 Sample Size Determination

The sample size was arrived at by considering the recommendation by Kombo and Tromp (2006) that a sample size of 10% to 30% is representative enough for a study population. The respondents were therefore randomly selected on the basis of 30% of the target population.

The sample size was calculated per ward in every sub-county considering the number of registered mango farmers. Sixty six (66) respondents were selected form Arror, 56 from Tambach and 95 from Soy North making a total of 217 respondents. The results were obtained as shown.

The sampled respondents were exposed to post-harvest management methods as per their wards and allowed to use the methods over a period of three months. This was carried out at Cheptebo Conference Centre. The farmers were asked to evaluate how it felt to use various post-harvest techniques after the stated period of time and also determined the economic advantage of using them. The information was collected using a questionnaire and triangulated using a FGD.

The crops under study were harvested at physiological maturity. For the case of mangoes, the respondents harvested them before they were fully ripe to reduce post-harvest damages of the fruits.

The farmers were exposed to the following post-harvest management methods.

1. Simple fruit harvesting tool. This tool was used for harvesting mangoes and it was designed in a way that the picking pole had a bag attached to it to prevent the harvested fruits from falling to the ground and a scissor to cut the fruit such that 10-20mm of the stalk is left on mango. The pole was long enough to enable picking of the fruits from the ground.
2. Solar dryer. This was used for the purpose of preserving mangoes and maize. After harvesting mangoes, pre-processing of ripe mangoes was carried out. This included: sorting to obtain good quality fruits which were free from damages, pests and diseases, cleaning which was basically washing in clean water and detachment of the stalk. Peeling was done using a sharp knife and the seeds removed while the flesh was chopped into small pieces. The slices were dipped into hot water (70^{0}C) for 5 minutes to retain the original color. The blanched slices were then placed in trays to dry for a period of 8-12 hours depending on the thickness of the cut pieces. During this process flipping of trays was done for even drying to enhance moisture levels of less than 10%. The dried mangoes were packed in transparent plastic bags.

3. Hand driven milling machine. This was a processing machine which was used for changing maize and the dried fruits into suitable form that could be used for preparing various products such as ugali and porridge from maize flour and mango powder from dried mangoes.
4. Maize flour fortification. Value addition through fortification was done to increase the content of essential nutrients such as vitamins and minerals. Maize was first dried, hulled precooked, dried then ground into flour. The flour was mix with sifted mango powder and ground vegetables and the flour mixture was packed in closed plastic tins which was later used to prepare products such as ugali.

2.5 Data collection and Analysis

Focus group discussion (FGD_s) and interview schedules were used to collect qualitative data whereas structured questionnaires were used to gather quantitative data.

Data was analyzed using computer SPSS, Version 22. Descriptive and inferential statistics was used. Pearson correlation coefficient and multiple regression procedures were used to establish the relationship of socio-economic and institutional factors influencing adoption of post-harvest technologies. The analysis was done at a confidence level of 95%.

2.5.1 Multiple regression

Multiple regression was used to determine the strength of relationship between socio-economic, institutional factors and adoption of post-harvest technologies. The equation below describes how the dependent variable Y is related to the independent variables $X_{1 \ldots\ldots\ldots} X_n$.

$Y = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 \ldots\ldots\ldots\ldots\ldots \beta_n x_n$, Where; y is the dependent variable (post-harvest technologies) $\beta_o =$ is the constant $\beta_1, \beta_{2 \ldots\ldots} \beta_5$ are the regression coefficients. $X_1, x_{2 \ldots\ldots} X_5$ are the independent variables.

3. RESULTS AND DISCUSSION

3.1 Attributes of Post-harvest Technologies

Post-harvest technologies were discussed in terms of the attributes that influenced adoption as follows:

3.1.1 Relative advantage of the post-harvest technologies

a. Simple fruit harvesting technology

The farmers were asked to determine the economic, social and environmental advantage of using the simple harvesting tool. The following advantages were identified; the fruit has a bag attached to it to prevent the fruit from falling to the ground thus minimizing damages. The tool has a scissors designed to cut the fruit off from its stalk and this helps to increase the fruit shelf life for up to one week. Compared to the indigenous harvesting method of caning or hitting the fruit with some object, this cutting process prevents bruises that would be formed should the farmer use the alternative harvesting method.

b. Solar drying technology

The farmers were asked to determine the economic, social and environmental advantage of mangoes using a solar dryer. The respondents were also to compare the advantages of using the improvised solar dryer and the open air drying that was used by most households. Solar drying machine was found to improve the availability of mangoes during off peak period and preserves the fruits and vegetables that would otherwise be disposed. As opposed to open air drying, solar dryer was faster because inside the dryer it is warmer than outside, less risk of spoilage because of the speed of drying

Table 1. Sample size determination

Sub- County	Ward	Number of registered mango farmers	Sample size
Keiyo North	Tambach	185	56
Keiyo South	Soy North	315	95
Marakwet West	Arror	219	66
Total		719	217

Source: Sub-County Agricultural offices (2019)

Fig. 1. Mango harvesting tool

Fig. 2 solar dryer

(If the drying process is slow the fruit start to ferment and the product is spoilt). The product is protected against pests, rain and dust, it is labor saving, the product can be left in the dryer overnight especially during rainy season. The quality of the product is better in terms of nutrients, hygiene and colour.

c. Hand driven milling machine

The farmers were asked to determine the economic, social and environmental advantage of using the mentioned machine to mill dried fruits and vegetables to be used to fortify maize. The machine was identified to be having the following advantages; each group of individuals will own a milling machine hence making it convenient to mill their product, it will prevent mixing of food materials which result when the same milling machine is shared. It will also save time of walking to a mill and reduces the cost of milling every other time.

d. Fortification of the cereals using fruits and vegetable

To provide a new value chain for fruit and vegetables and also to improve the nutritional status of the vulnerable children, youth and the elderly, farmers were exposed to fortification of maize flour. The farmers were then asked to discuss the comparative advantages of the fortified maize over the traditional products. The discussion highlighted the following advantages; the fortification will make good use of the dried fruits and vegetables thereby opening a new value chain for the products. It will improve the nutritional level of the vulnerable members of the society.

3.1.2 Level of compatibility of the technologies

This was determined by the ability of the new post-harvest technologies to spread through the smallholder farmers living in Kerio Valley. The compatibility of the innovation would be measured against the existing technologies. The compatibility aspect will consider several factors including the additional cost of the innovation, quality of work output and disruptions of the social norm.

a. Simple fruit harvesting technology

The improved harvesting rod was more compatible compared to the traditional pole used to hit the fruits off the trees. Actually most farmers (94%) indicated that they would modify their harvesting tool by introducing the cutting equipment and the bag attachment. The farmers however noted that the tool needed to be reinvented to be able to harvest pawpaw since the one displayed was appropriate for mangoes. The opening of the chute needed to be widened and material for the rod made stronger to withstand the weight of the pawpaw fruit.

b. Solar drying technology

This technology was compared to open air drying which cost absolutely nothing compared to this technology. All farmers (100%) agreed that despite having several advantages over the open air drying, the technology would be hard to adopt since it required more capital investment.

c. Hand driven milling machine

The milling machine was found to be compatible but would introduce some economic disruptions in the social system. This means that the farmers would abandon the commercial mills for the hand driven machine. The farmers (87%) argued that the investment cost for the hand mill made no economic sense since it was selling at a very high cost to the family. For the farmers to adopt this technology they would require subsidies.

d. Fortification of the cereals using fruits and vegetable

This method of preservation was compatible since it introduced a better use for surplus fruits and vegetables. Apart from the labour required to chop the fruits, 92 percent of the farmers considered the technology more viable to their social and environmental situation.

3.1.3 Level of complexity of the post-harvest technologies

The farmers were also asked to determine the level of complexity of the technologies where they were to give their perception on the degree of complexity of the technologies and the results were as follows.

Depending on the ease of a technology to be understood and used, each technology was rated in a five Likert scale. From Table 2 above, a majority of farmers (94%) indicated that the fruit harvesting rod was lowly complex since it was a modification of what they had been using. This therefore implied that they would easily adopt the technology. Six percent (6%) of the farmers indicated that the harvesting tool was complex. On the solar drying machine, 4 percent of the farmers rated that the machine would be moderately complex, 8 percent indicated that the machine would be complex and a majority (88%) indicated that the solar drying machine would be lowly complex to use. The hand driven milling machine was also rated and 89 percent of the farmers indicated that the machine would be lowly complex therefore more easily to be adopted whereas 11 percent indicated it has complex. Finally on value addition of cereals through fortification of fruits and vegetables, 19 percent indicated that the technology would be moderately complex, 12 percent complex and 69 percent indicated that it would be lowly complex. Most of the farmers rated the technologies has lowly complex thus implying that they were likely to adopt them, however other traits of the same technologies would also influence its adoption.

3.2 Socio-economic and Institutional Characteristics of the Respondents

The distribution of the mentioned factors were determined and their percentages calculated based on the farmer's response on likeability of the factors to influence adoption of post-harvest technologies of maize and mango. The results were summarized in Table 3.

Table 2. Level of complexity of post-harvest technologies

Post-harvest technologies	N	VHC%	HC%	MC%	C%	LC%
Harvesting rod	217	0	0	0	(13)6	(204)94
Solar dryer	217	0	0	(9)4	(18)8	(191)88
Hand milling machine	217	0	0	0	(24)11	(193)89
Fortification of cereals	217	0	0	(42)19	(26)12	(149)69

N=217, key; VHC=very highly complex; HC= highly complex; MC= moderately complex; C= complex; LC= lowly complex

The majority (154; 71%) of the respondents were in the age bracket of 25-45 years. Seventeen percent (17%) between 45-55 years and 12 percent above 55 years. On their response in regard to likeability of age to influence adoption of post-harvest technologies, 36% of the respondents strongly agreed, 37 percent agreed, 10 percent were undecided whereas 9 ad 8 percent disagree and strongly disagree respectively. Fifty six (56) percent of the young respondents (age 25-35 years) strongly agreed that age influenced adoption of post-harvest technologies.

On gender distribution, 157 (72%) of the respondents were male whereas 60 (28%) were female. On the influence of gender on adoption, 24 percent of the farmers strongly agreed, 16 percent agreed, 11 percent were undecided whereas 22 and 27 percent disagreed and strongly disagreed respectively on gender likeability to influenced adoption.

The respondents were also asked to indicate their education level. A majority 84(39%) had primary level of education, 80(37%) had secondary education and 53(24%) had tertiary level of education. Further on the education level, 41 percent of the respondents strongly agreed on influence of education on adoption, 31 percent agreed, 14 percent were undecided whereas 11 and 3 percent disagreed and strongly disagreed respectively on the same.

On income levels, majority of the respondents (84%) strongly agreed, (11%) agreed, none was undecided whereas 2 percent disagreed and 3 percent strongly disagreed that income level would influence adoption of post-harvest technology. On extension services, 46 percent of the respondents strongly agreed, 40 percent agreed, 4 percent were undecided, 6 percent disagreed whereas 4 percent strongly disagreed on influence of extension services on adoption.

Furthermore, multiple regression analysis was computed to check whether there was a significant relationship among the factors and adoption of post-harvest technologies. The results were presented in Table 4.

From the results tabulated, coefficient of determination (R^2) indicated that 94.4% of the variation in adoption of post-harvest technologies would be predicted from the independent variables (gender, age, education level, and income and extension services). In addition, it was indicated that the contribution of the independent variables were significant (F (5, 211) = 714.932, P<.001). This showed that the model was significant and therefore the independent variables reliably predicted the dependent variable.

Table 3. Respondent's socio-economic and institutional factors on adoption of post-harvest technologies

Variable	N	SA%	A%	U%	D%	SD%
Age						
25-35	77	(43)56	(23)30	(8)10	(3)4	0
36-45	77	(18)23	(27)35	(10)13	(16)21	(6)8
46-55	36	(14)39	(11)31	(4)11	0	(7)19
Above 55	27	(3)11	(20)74	0	0	(4)15
Total	217	(78)36	(80)37	(22)10	(20)9	(17)8
Gender						
Male	157	(29)18	(25)16	(15)10	(40)25	(48)31
Female	60	(23)38	(10)17	(10)17	(7)11	(10)17
Education level						
primary	84	(35)42	(24)29	(7)8	(11)13	(7)8
secondary	80	(26)33	(25)31	(17)21	(12)15	0
Tertiary	53	(27)51	(19)36	(7)13	0	0
Total	217	(89)41	(67)31	(31)14	(23)11	(7)3
Income	217	(182)84	(24)11	0	(4)2	(5)3
Extension services	217	(100)46	(87)40	(8)4	(13)6	(9)4

N=217, key; SA=strongly agree; A= agree; U= undecided; D= disagree; SD= strongly disagree

Table 4. Multiple regression analysis of socio- economic factors on adoption of post-harvest technologies

Model (n=217)	R square	Beta	t- value	Sign	Pearson's correlation
Dependent variable					
Post-harvest technologies					
Constant			-5.329	.000	1.000
Gender		-.143	-8.623	.000	-.246**
Age		.051	2.983	.003	.350**
Education level		.707	16.342	.000	.953**
Income level		.105	4.736	.000	.656**
Extension services		.161	3.488	.001	.907**
R^2 squared	0.944				

F (5,211) =714.932 P<.001 Adjusted R^2 =0.943

To further know the extent to which each independent variables could contribute towards the dependent variable, multiple regression equation was defined as per the variables of the study as follows: Y= post-harvest technologies; x_1 = gender; x_2 = age; x_3 = education level; x_4 = income level; x_5 = extension services. This definition was substituted in the multiple regression equation and was given as: $y = 5.327-0.143x_1+0.051x_2+0.707x_3+0.105x_4+0.161x_5$. This was further discussed as follows:

Gender, age, education level, income and availability of extension services significantly influenced the adoption of post-harvest technologies. Results on gender distribution shows that seventy two (72%) of the respondents were male while 28 percent were female. This indicated that majority of the households were male headed. Gender significantly and negatively influenced the adoption of post-harvest technologies (r= -.264, *P*<.001). This could mean that there was weak correlation between gender and adoption of technologies. In this study both male and female respondents were involved in farming activities meaning that irrespective of the gender farmers were willing and ready to embrace new post-harvest technologies to safe their production and improve their livelihoods since all farmers in the study area underwent the same problem of post-harvest losses.

Age had a positively significant influence on the adoption of post-harvest technologies (r=.350, P<.05). Younger farmers have been taken to be more willing to adopt the technologies than the older farmers. This therefore could be associated to older farmers being more conservative and greatly risk averse to new technologies whereas younger farmers can easily be convinced, perceived to be optimistic and curious to try a technology expecting changes on regard to their agricultural productivity [19, 20, 21]. However, this perception was contrary to the current study considering the relationship between age and education level. There was significant correlation between age and education (r=.307*.* *P*<.001).This was presented in the Table 5.

Based on the results above, it was concluded that despite of age category, education level was considered as one factor that would influence farmers to adopt new technologies. Majority of the respondents were in the age bracket of 25-45 years. This therefore meant that young farmers were interested in farming and in regard to their level of education, those with high education level would probably embrace and take up new post-harvest technologies.

Table 5. Relationship between education level and age of respondents

	Value (r)	Sig.(2 tailed)
Pearson's correlation	.307	.000
spearman's rho	.346	.000

P<.05

Education had a positive significant influence on adoption of post-harvest technology (r=.953, *P*<.001). This is because higher education level has been taken to increase farmers' ability to obtain, process and use information relevant to adoption of a new technology. Formal or informal education greatly supply farmers with important information and skills on production, management and marketing. Moreover, higher education influences farmers' attitude and decision hence making them more open, rational and able to analyze the benefits of the technology. This eases introduction and entry of a new technology which will ultimately influence adoption process. The results supported the findings of [22, 20, and 23].

Income levels(r= .656, *P*<.001) and availability of extension services (r= .907, *P*<.001) significantly and positively influenced the adoption of post-harvest technologies. This could be associated to the fact that increased in income levels increases the likeability of an individual to easily try a technology because of their ability to meet the technology cost requirement. In addition, off-farm income greatly influence technology uptake since it gives farmers an extra income source to acquire productivity inputs and meet the cost of production. Income level of a farmer has been associated to the cost of a technology. This is based on the net gain to a farmer from adopting a technology and the cost of production in the sense that more affordable and productive technology will be easily adopted than a high cost technology with more relative advantage than the existing one. The results supported the study by [20].

Availability of extension services also influenced adoption because access to information enables the farmers to learn the existence as well as the effective use of a technology thus reducing uncertainty about technology's performance. Moreover, extension services can counteract the negative effect of lack of formal education of farmers which may hinder technology adoption. Farmers get a lot of information regarding production, processing and marketing from extension services and also through a farmer to farmer network. This results concurred with that of [22, 24, and 19].

4. CONCLUSION AND RECOMMENDATION

The findings revealed that socio- economic and institutional factors had influence on adoption of post-harvest technologies. This therefore suggests that agricultural information awareness and specifically capacitating farmers on post-harvest management should be enhanced in order to curb post-harvest losses. Farmers should be equipped with the basic knowledge on post-harvest handling and extension services should be prioritized since this could greatly persuade farmers to embrace and try new technologies.

CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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