POTENTIAL ECONOMIC IMPACT AND WILLINGNESS TO PAY FOR POSTHARVEST TECHNOLOGIES OF MANGOES AND THEIR VALUE-ADDED PRODUCTS AMONG PRODUCERS AND CONSUMERS IN KENYA

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This thesis is my original work and has not been submitted for a degree in any other University.

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To God, Mr. Daniel Mujuka (RIP my father), Mrs. Mary Mujuka (my mother), my siblings, Peter my spouse, Shana and Mary our daughters, Emmanuel our son, relatives, friends and colleagues.

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LIST OF ABBREVIATIONS

AgGDP	Agricultural Gross Domestic Product
ASGTS	Agricultural Sector Growth and Transformation Strategy
AEZ	Agro-ecological Zone
BCR	Benefit – Cost Ratio
CS	Consumer Surplus
CBA	Cost Benefit Analysis
CVM	Contingent Valuation Method
ECC	Evaporative Charcoal Cooler
ECT	Evaporative Cooling Technology
ESM	Economic Surplus Model
FAOSTAT	FAO Statistical Database
GI	Geographic Indications
Ha	Hectare
HCDA	Horticultural Crops Development Authority, Kenya
HCD	Horticultural Crops Directorate
IRR	Internal Rate of Return
KALRO	Kenya Agricultural and Livestock Research Organization
KES	Kenya Shillings
LH	Lower Highland Zone
LM	Lower Midland Zone
MT	Metric Tonne
NPSDM	Naturally Preserved Solar Dried Mangoes
NPV	Net Present Value

OLS	Ordinary Least Squares
PHL	Postharvest Loss
PICS	Purdue Improved Crop Storage
PHLRT	Postharvest Loss Reduction Technology
PSVAT	Postharvest Storage and Value Addition Technology
PS	Producer Surplus
RUM	Random Utility Model
R & D	Research and Development
SSA	Sub-Saharan Africa
SDG	Sustainable Development Goals
UoN	University of Nairobi
UH	Upper Highland Zone
UM	Upper Midland Zone
VIF	Variance Inflation Factor
WTA	Willingness to Accept
WTP	Willingness to Pay
YWI	YieldWise Initiative
ZEBC	Zero Energy Brick Cooler

ABSTRACT

Postharvest loss reduction is increasingly recognized as a promising strategy for ensuring food and nutrition security. Historically, horticultural research has focused on increasing production with little emphasis on minimization of postharvest losses (PHLs). In Kenya there is need to reduce PHLs estimated at up to 50% in mangoes. Low adoption of postharvest loss reduction technologies (PHLRTs) and poor access to remunerative markets are considered as key drivers of the postharvest losses. Reduction of PHLs require adoption of cost effective and acceptable PHL reduction technologies. It is against this background that the Rockefeller Foundation is supporting a postharvest project started by the University of Nairobi (UoN) to create awareness and provide applicable PHLRTs to smallholder farmers. Some of these technologies are tunnel solar dryers, charcoal and brick coolers.

Charcoal coolers and zero energy brick coolers are off-grid evaporative cooling technologies which are appropriate for smallholder farmers without access to electricity. Further, they are constructed from locally available materials making them accessible to resource-poor smallholder farmers. Solar dryers reduce PHLs through drying of fruits and vegetables into more shelf stable products such as mango leather and mango crisps which fetch higher prices than the equivalent quantities of fresh mango fruits. Though they are so important in this respect, their potential economic impact on smallholders has not been well studied. Globally, these technologies are not new but their adoption in Kenya is limited, and factors affecting their utilization and consumption of their value-added products are not well understood.

Therefore, the purpose of this study was to estimate the expected return on investment in PHLRTs and willingness to pay (WTP) for the PHLRTs and their value-added products among producers and consumers in Kenya. Specifically, the study sought to: (1) Estimate

the potential economic impact of PHLRTs among smallholder mango farmers in Embu County; (2) Analyze smallholder mango farmers' WTP for PHLRTs and its influencing factors; and (3) Assess consumer awareness and WTP for solar-dried mangoes that are naturally preserved in Nairobi County, Kenya.

Theoretically, this study is anchored on welfare economics and the random utility maximization theory. The potential benefits of investing in PHLRTs were estimated using the economic surplus model. The WTP was estimated using a double hurdle model. Consumer awareness and WTP for naturally preserved solar dried mangoes (NPSDM) were analysed descriptively, while a tobit model was employed to assess the determinants of WTP. Multistage sampling procedure was adopted in this study. Embu and Machakos Counties were purposively selected. Farmers in these Counties had previously been trained on proper agronomic practices to reduce preharvest losses. These Counties also contribute significantly to the total mango production in the country.

The proportionate to size sampling was used to determine the sample size in Masii and Karurumo Locations of Machakos and Embu Counties, respectively. Systematic random sampling was used to select 320 mango farmers in Masii and Karurumo Locations. Rising incomes in urban centres is associated with increased expenditure on healthy food choices, particularly fruits and vegetables. Nairobi county was chosen for the consumer survey since it is the main consumption area of the dried fruit products. Accidental sampling procedure was employed in selecting 414 buyers (consumers) from Zucchini, Carrefour, Chandarana and Tuskys supermarkets in Nairobi. Quantitative and qualitative research designs were used in this study. Both primary and secondary data were collected using semi-structured questionnaires, literature review and key informants.

A cost–benefit analysis (CBA) of the postharvest project revealed that investment in the proposed PHLRTs is viable. This profitability heavily depends on uptake of the

technologies and the cost of capital. It was found that the farmers' likelihood of paying for PHLRTs and WTP amount were positively influenced by price, agricultural group membership and income from mangoes. Another significant factor was gender, which negatively and positively influenced the probability to pay in Embu and Machakos, respectively. However, age, experience, land tenure, market access and credit access significantly influenced WTP amount negatively. Results revealed that the WTP amounts for the PHLRTs were lower than the market prices.

Only 16% of the consumers were aware of solar dried mangoes. However, consumers were willing to pay 29% more for NPSDM, with most of them interested in taste. This WTP was found to be positively influenced by access to mass media for information on food, purchase of mango products in retail stores and having tasted naturally preserved mangoes. Therefore, promoting the product through the media and within the retail stores is necessary to increase awareness and demand. These findings are vital in developing niche markets for NPSDM.

The study concludes that investment in PHLRTs is viable and consumers are willing to pay a premium for NPSDM. Further, viability of the technologies is expected to be higher at higher adoption rates. However, the producers' WTP amount was lower than the market rate. Thus, the government should spur demand through enhanced extension programmes and short-term price subsidies. Promotion of products resulting from the tunnel solar dryer should also be undertaken to trigger demand among consumers.

Keywords: Cost-Benefit Analysis; double hurdle model; economic surplus; postharvest loss; Tobit model; WTP

CHAPTER 1: INTRODUCTION

1.1 Background

The estimated global postharvest losses in 2017 was adequate food for about 940 million adults (Abbade, 2020). The major causes of postharvest losses (PHLs) in horticultural produce are lack of postharvest technologies and market access (Bart et al., 2021; Mengistie et al., 2021). The high magnitude of PHLs is increasingly raising concern in the policy arena (FAO 2019a; World Bank 2011). It is argued that reduction of the PHLs will increase access to food at lower prices thereby improving global food and nutrition security. A key policy strategy for ensuring food security in 2050 is investment in PHL reduction (Bart 2021; Belik, 2018; Kikulwe et al., 2018). Local, regional and international efforts to reduce postharvest losses exist.

The mango (Mangifera indica L.) is one of the common and extensively produced fruit throughout the world (Katoch et al. 2019) due to its economic and nutritional benefits. Apart from the well documented nutrients, vitamins and minerals, mangoes also possess other vital medicinal properties (Maldonado - Celis et al., 2019; Vithana et al., 2019). Mango production volumes are higher in developing countries due to an ever-increasing global demand (FAO, 2018).

In Kenya, mango production has maintained an upward trend annually and the fruit is second to the banana with respect to output and acreage (HCD, 2020). About 56,437 Ha are under mangoes in Kenya with a production of 809,857 Metric Tonnes (MT) valued at over KES 15 billion (HCD, 2020). The mango sub-sector accounts for about 5% of the Agricultural Gross Domestic Product (AgGDP) and about 2% of the national GDP. The sub-sector further employs a significant proportion of the population in Kenya on a seasonal basis (GoK, 2018). Approximately 98% of the mangoes are sold domestically, making the mango sub-sector one of the main sources of income for most smallholder farmers in mango producing areas (Grant et al., 2015; HCD, 2020). Only 2 percent of the mangoes from Kenya are exported. Nonetheless, the crop is growing as an important export crop having been the third largest fruit exported in 2020 and having contributed 6 percent of the total value of fruit exports (HCD, 2020).

The development of the mango value chain is threatened by postharvest losses (PHLs) estimated at up to 50% (KALRO, 2021). The magnitude of the PHLs vary with mango variety, postharvest handling practices and available postharvest loss reduction technologies (PHLRTs) (Perumal et al., 2021). This is the case in a country where 25% of the population (13 million) is undernourished and a similar proportion is severely food insecure (FAO 2021). At the ripening stage, mangoes experience changes which increase their perishability during handling after harvesting and when the produce is stored (Wei et al., 2021). This nature of mangoes is responsible for significant PHLs depending on how the produce is handled after harvest (Ntsoane et al., 2019).

Mango fruit production is a source of livelihood for resource poor farmers, foreign exchange and raw material for the processing industry. Mango PHLs negatively affects both producers and consumers due to the reduction in the marketable produce which in turn reduce producer’s household income and access of the commodity by consumers. In developing countries both quantitative and qualitative PHLs occur during harvesting all the way to marketing. The losses affect the entire supply chain due to limited access to postharvest technologies (Ntsoane et al., 2020).

Wholesale markets often lack adequate facilities for postharvest handling, most importantly for temporary storage. Coupled with that, lack of communication between food chain actors, inadequate infrastructure and maladapted economic conditions hamper performance (FAO, 2014a). Actors’ interactions with external factors including governance structures, infrastructure and flow of information (Humble and Reneby, 2014) and lack of awareness on the significant food waste which need to be reduced (Shukla and Jharkharia, 2013) also affect the efficiency of supply chains.

It is against this background that a postharvest project sponsored by Rockefeller Foundation through the UoN aimed at upgrading two horticultural aggregation centers in Eastern Kenya. The project sought to provide proven PHLRTs such as evaporative charcoal coolers (ECCs), zero-energy brick coolers (ZEBCs) and Coolbot^{TM} cold storage technologies (Karithi, 2016; Shitanda et al., 2011). These technologies are not new globally but their adoption in Kenya is limited. The ECC and ZEBC are evaporative cooling technologies which allow water to evaporate from wet charcoal in the ECC or sand in the ZEBC. The evaporation cools stored produce and the higher relative humidity around it further reduces perishability. Evaporative cooling technologies can store up to 5 tonnes of mangoes.

Processing of mango fruits extends their shelf life, improves their value and reduces PHLs. Therefore, the project also seeks to upgrade processing equipment in order to attain dried products with longer shelf life and extended marketing period. Tunnel solar dryers which can dry up to 1 tonne of mangoes at a time were to be provided. Dried mangoes fetch higher prices and have a longer shelf life.

1.2 Problem Statement

Historically, the horticulture sector has focused on research geared at increasing production of high-quality produce with little emphasis on postharvest handling. Consequently, high quality fruit and vegetables are produced *en mass*, but up to 50% of this produce fails to reach the consumer since postharvest measures are not put in place. Postharvest research is therefore critical for efficient supply chains and enhanced food security (Bantayehu et al., 2019; FAO, 2019a; Tarekegn and Kelem, 2022). The extent of PHLs and both the available technologies and market development are strongly correlated. Mango production in Kenya has been increasing annually and with only 2% of the produce making it for export, most of the mangoes are traded locally as fresh fruit. This is because there is limited investment in agro processing.

Most producers in Embu individually sell their mangoes to middlemen. This predisposes them to exploitation by middlemen who purchase the mangoes at KES. 2-5 per piece (Maloba et al. 2017; Muthini et al. 2017) during the peak season. According to Osena, 2011 the gross margins that accrue to farmers, brokers, wet processors and dry processors per mango piece are KES. 3.2, KES. 5.6, KES. 7.6 and KES. 24, respectively.

Processed mangoes fetch higher prices than fresh mangoes and are more profitable. For instance, the average farm gate price of a kilogram of fresh mango fruit in Kenya and Ghana is USD 0.3 while the average price of mango crisps in Kenya and Ghana is USD 7 and USD 20 (Adams et al., 2019; Musyoka et al., 2020). A feasibility study of smallholder investment in processing of mangoes into mango chips in Ghana revealed a return of USD 1.18 for every dollar and a payback period of 1 year and 5 months.

In a bid to address their marketing challenge, reduce PHLs and improve profitability, some farmers have formed groups to aggregate their mangoes and also to do small scale processing into shelf stable products such as juices, mango chips and mango flour. However, these groups lack the capacity to aggregate and produce high quality processed products that can be marketed widely. It is imperative to augment innovations that are deemed successful in primary production with correspondingly appropriate innovations in marketing (Muthini et al., 2017).

High PHLs in mangoes is due to lack of cold storage facilities to preserve fresh fruits and lack of processing facilities to transform the fresh produce into shelf stable products during the high season. Simple and effective storage and processing technologies such as

ECCs, ZEBCs and tunnel solar dryers are applicable PHLRTs which can increase smallholder income and reduce poverty. Past international horticultural postharvest project interventions are rarely, if ever, re-evaluated once they are completed to determine whether the interventions promoted during the project have been sustained (Kitinoja, 2010). Therefore, little is known on the extent of their potential economic impact. It is therefore imperative to estimate the return on investing in these PHLRTs given the multiple alternative uses to which the scarce resources at stake can be invested in. Further, it is not known whether the proposed technologies and their value-added products are acceptable among producers and consumers. Thus, this study made an attempt to address these research gaps.

1.3 Objectives

The purpose of this study was to assess the economic feasibility and willingness to pay for postharvest technologies of mangoes and their value-added products among producers and consumers in Kenya.

The specific objectives of the study were to;

i. Assess the *ex-ante* economic returns to investment in postharvest loss reduction technologies among smallholder mango farmers.
ii. To analyze farmer's willingness to pay for postharvest loss reduction technologies among smallholder mango farmers.
iii. To assess consumer awareness and willingness to pay for naturally preserved solar-dried mangoes.

1.4 Hypotheses

The hypotheses tested in the study were that:

i. There are no *ex ante* economic returns to investment in postharvest loss reduction technologies among smallholder mango farmers.

ii. Smallholder mango farmers are not willing to pay for postharvest loss reduction technologies
iii. Consumers are not willing to pay for naturally preserved solar-dried mangoes.

1.5 Justification

The contribution of investment in agricultural research in sub-Saharan Africa (SSA) is widely recognized. However, meagre commensurate efforts exist in summarizing and assessing returns to such investments (Demont et al., 2009; Pardey et al., 2016). One of the competitive investment alternatives for national governments and investors is agricultural research. Funding of investment alternatives depend on reliable evidence of the potential benefits associated with each investment (Maredia et al., 2000).

The Kenya's Food and Nutrition Security Policy acknowledges the significant PHLs across all value chains due to shortage of relevant infrastructure (GoK, 2011). Consequently, the government seeks to promote storage and processing of agricultural produce through supporting private players involved in postharvest management in the country. This study is in line with the County Integrated Development Plans of Embu and Machakos Counties that acknowledge high PHLs of horticultural produce. The Counties are committed to promote cold storage, agro-processing and value addition.

Returns to investment in PHL reduction technologies will provide information that will contribute to planning for research, priority setting, guide adoption and investment decisions by farmers, donors and policy makers. Further, the results will shed light on the acceptability and replicability of the proposed technologies indicating, barriers to adoption, which are useful in improving the technologies for widespread adoption. The mean WTP for both the technologies and their value-added products will guide pricing decisions and product development. The PHL reduction technologies, if found viable, have the potential to reduce the malnourished population in Kenya and beyond through the saved fruit, estimated at 50%.

The uptake of the proposed PHL reduction technologies could be instrumental in poverty reduction through increased productivity and therefore household incomes, thereby contributing to the achievement of the Agricultural Sector Growth and Transformation Strategy (ASGTS), Kenya Vision 2030 and the African Union's agenda 2063 which aim at upgrading value addition of agricultural commodities for renewed economic growth. This study is in tandem with the United Nation's Sustainable Development Goal (SDG 12.3) which targets significant reduction of PHLs by the year 2030. The novelty of this study is its contribution to research and development (R&D) by assessing the potential economic impact of the proposed technologies and their acceptability among producers and consumers.

1.6 Scope and limitations

This study focuses on viability of investment in PHLRTs, their acceptability among producers and consumer demand for the resulting value-added products. The ex-ante nature of the first objective called for heavy reliance on secondary data and opinion of experts. The potential bias of respondents may compromise the reliability of the estimates. Information on price elasticities of mangoes was limited. In the absence of elasticity information, estimates from neighbouring regions with similar market structure were used. Where no demand and supply elasticities are available for a country, its elasticity is assumed to be the same as those that prevail in a geographically close proxy region (Giblin and Mathews, 2005). However, evidence on the fact that the economic feasibility of PHLRTs is less sensitive to elasticities than to other critical parameters such as adoption rates, expected cost and yield changes, exists. The consumer survey conducted in this study focused on high end retail outlets where dried mangoes are sold. Given the high-end nature of the target outlets, the management restricted collection of sensitive information and the length of the interviews. Therefore, this study failed to control for other market related and socio-demographic factors which would influence WTP for naturally preserved solar-dried mangoes (NPSDM) such as packaging, pricing, nationality, income, household size and composition.

1.7 Organization of the thesis

There are six chapters in this thesis. Chapter 1 presents the background, specific objectives, hypotheses, justification, scope and limitations of the study. Chapter 2 presents literature reviewed and theoretical framework. This chapters focuses on review of possible strategies for ensuring global food and nutrition security. Postharvest loss reduction is presented as an urgent and sustainable strategy. Focusing on the mango value chain in Kenya, applicable and proven PHLRTs are proposed for the reduction of the high PHLs in the value chain. Chapter 3 presents the general methodology while Chapters 4 to 6 show results of the specific objectives. Chapter 7 finally provides an overall summary, conclusions and policy implications of the findings.

CHAPTER 2: LITERATURE REVIEW

2.1 Postharvest losses and applicable postharvest technologies for horticulture

Global food production should increase by 1.3 percent annually to meet future demand (FAO, 2012). Sustainable achievement of this growth requires increasing food production through intensive agricultural production (Wu et al., 2018). Increasing crop yield through agricultural intensification has been a challenge in areas affected by climate change (Pugh et al., 2016). Cropland expansion apart from threatening biodiversity, also has an impact on storage of carbon (Molotoks et al., 2018). As a result, PHL reduction has been proposed for sustainable food and nutrition security (Abbade, 2020; Chickez et al., 2021; Mengistie et al., 2021). PHL reduction also ensures efficiency in the use of resources and reduction of environmental degradation.

Mangoes are the second largest fruits demanded in the world and their value increase with value addition (Altendorf, 2017; Chappalwar et al., 2020). Smallholder farmers in Kenya contribute about 80% of the total mangoes produced in Kenya (KALRO, 2021). The mango value chain has great potential but which is not fully exploited due to high (40% - 50%) postharvest losses and lack of access to prime markets (KALRO, 2021; Kimiywe, 2015). This is attributable to the fact that mango processing is low in the country and thus there is limited investment in agro-processing and value addition (Mulinge et al., 2015). The perishable nature of mangoes poses the need for appropriate postharvest handling technologies (Kayier et al., 2019).

Given the perishable nature of mangoes, value addition has been proposed for the reduction of postharvest losses, enhanced shelf-life, market access and smallholder household income (Donkor et al., 2018; Salvioni et al., 2020). Moreover, addition of mango value has potential to increase employment opportunities given the labor-intensive nature of the venture. According to Anna et al. (2020) assessment of postharvest technologies is necessary given the transportation of mangoes to nonproducing areas and the need for storage to ensure supply throughout the year.

However, in Kenya, value addition among smallholder farmers is limited and estimated at only 6% (Ntale et al., 2015). Makueni County is one of the Counties that has heavily invested in the value addition of mangoes (GoK, 2019). The County spent $10M USD in 2017 to put up a processing plant that processes mango into puree (mango concentrate) (Henning and Mbithi, 2021). While the plant could process up to 5 MT of mangoes into 3,000 litres of puree per hour, its operation was challenged by lack of mangoes when mangoes were out of season and frequent power outages which threatened its shut down (Mwende, 2022).

Smallholder farmers lack awareness on the numerous technologies of adding value to fresh mangoes (Thayalan et al. 2020) some of which are off grid and extend shelf. One of the technologies is a solar dryer which relies on direct sun radiation for drying of mangoes into mango leather and mango crisps (Steve, 2010) which fetch higher prices compared with similar quantities of fresh mangoes. Smallholder interest in value addition apart from being influenced by institutional, economic, and socio-demographic factors, it is also largely influenced by markets, support services, processing technologies and infrastructure (Gashaw et al., 2018).

Solar dryers rely on direct sun radiation and work based on the resulting greenhouse effect. They have three main components which are; a drying chamber for drying food, a solar collector that heats the air, and an airflow system. Solar dryers can dry horticultural produce thus increasing shelf life by up to one year. The shelf life of fresh mangoes is short and highly depends on storage conditions. Low temperature reduces metabolic activity, loss of water, incidences of disease, insect attack, delays ripening and senescence, reducing PHLs (Wayua et al., 2012). Conventional cold rooms apart from being costly, they are also not applicable for smallholder farmers, due to high operation costs and limited access to electricity.

Evaporative cooling technologies (ECTs) which are low-cost storage technologies made from locally available materials (Khan et al. 2017) using unskilled labor are promising to address cold storage challenges facing smallholder farmers. These technologies work through removal of heat from the produce through evaporation of water on the surface of the storage device. ECTs have successfully been used for storage of vegetables and fruits such as mangoes, increasing shelf life by up to more than two weeks compared to storage in ambient conditions (Kalpana et al., 2010).

Adoption of a PHLRT is a decision which is made depending on cost and expected utility. Agricultural training and extension programs have been found to be effective in promotion of agricultural technologies. Group participation has also been found to be important for information sharing and marketing. Examples of ECTs are zero energy brick coolers and charcoal coolers (Manyozo et al., 2018). Construction of the zero-energy brick cooler involves filling up sand between a double wall of bricks, while a charcoal cooler involves filling up charcoal between two wire nets. The sand and charcoal are constantly kept moist allowing evaporation of warm dry air from the stored produce hence cooling the produce.

2.2. Theoretical background

Ex-ante cost-benefit analysis, producer WTP and consumer WTP are anchored on welfare economics which studies how allocation of resources affects economic wellbeing (Marshall, 1920; Pareto, 1966; Pigou, 1952). Accordingly, the contribution of PHLRTs to social welfare is the difference between gross social benefits (producer surplus and consumer surplus) and social costs which results in net social benefits (potential economic impact). According to Hunt and Lautzenheiser (2011), welfare economics is generally divided into the consumer utility maximization and profit maximization by the firm theories, both of which simply demonstrate the logic of constrained maximization. Based on the utility and profit maximization, economists have proven that, under competitive conditions, utility-maximizing consumers and profit maximizing entrepreneurs automatically interact to maximize social welfare.

Welfare economics is concerned with social welfare maximization, based on Pareto efficiency and compensation principles. According to Bator (1958) given the initial wealth endowment, utility is enhanced through production and exchange in order to reach the maximum possible level based on the original distribution of wealth. Economists refer to this point on the utility-possibility frontier as a Pareto optimum point since it represents societal maximum welfare that is tenable from a given distribution of wealth. Competitive utility and profit maximizing behavior automatically lead to such a point. Individual maximizing behavior automatically takes society to a Pareto optimum point which economists refer to as the bliss point or the point of constrained bliss.

The Pareto efficiency criterion is used to compare or rank different economic states. A Pareto efficient state is a state of resource allocation where making an individual better off requires making at least one other individual worse off (Pareto, 1896). According to Hunt and Lautzenheiser (2011), the duality theorem emphasizes a relationship between Pareto efficiency and market performance. This relationship implies that decentralized decisions by individual profit and utility maximizers in response to prices only achieve inputs, outputs and commodity-distribution, that the maximum social welfare function allows. This suggest that decentralized market calculations accurately account for all economic costs and benefits that the appropriate welfare function is sensitive.

The compensation principle focuses on probable compensation as opposed to actual compensation since payment of compensation involves a value judgment (Kaldor, 1939;

Hicks 1939). The principle states that, state B is preferable to state A if, in moving from A to B, the losers can be compensated by the gainers such that at least one person is better off, and no one is worse off (Kaldor, 1939). According to Alston et al. (1995), the summation of changes in producer and consumer surpluses measure the net welfare change in the sense that those who benefit from PHLRTs could, in principle, compensate those who lose and still be better off. In that sense, compensation could mean reducing consumer benefits, possibly through taxes, in order to give subsidies to producers.

Since PHLRTs are expected to increase productivity through the saved fruit, mango prices are expected to fall. The taxes to consumers can be estimated by the maximum amount of money that consumers are willing to forgo to have an economic change (compensating variation). If mango prices remain the same after adoption of PHLRTs, the consumers would need to be given additional income (equivalence variation) to make them as well off without the price fall as they would have been with the price fall. The compensation principle assumes that such transfers could be made in a lump-sum fashion without any tax-induced distortions in consumption or production. When all losers are fully compensated and there are still some net gains, PHLRTs constitute a welfare improvement according to the *Pareto criterion.*

Following traditional welfare economics, use or utility derived from a good determines its value (Catalano et al., 2016). According to Bateman et al. (2002), value of a good can be determined with or without using a good and the non-use value can be classified into the bequest, the option and the existence value. At times the quasi-option value is considered (Broadman et al., 2001). The option value arises with the possibility to predict future use of a commodity which is not used currently. If knowledge on the future use of the good is scanty, and irreversibility exists, then the notion of quasi-option value is invoked. Contrarily from bequest (or altruism), option and quasi option values, the existence value is as a result of the utility that arises from the mere perception that the good exists, despite the absence of any anticipated use (Brun, 2002; Walsh et al., 1984).

2.3 Review of related empirical literature

Economic impact evaluations are classified as ex ante or ex post evaluations. Before project or program initiation, ex ante evaluations are undertaken (Alston et al. 1995) to aid in priority setting (Maredia et al., 2000). Ex-ante evaluations rely on projections on expected yield increases, success and adoption of proposed technology. After project implementation, ex post evaluation is carried out to estimate the resultant impact of a research project.

An economic assessment involving cost benefit analysis and WTP for hermetic storage technologies among smallholder farmers was conducted in Tanzania (AGRA, 2020). The study found demand for hermetic storage technologies increasing with awareness of the technologies among farmers. However, the study found a demand gap due to the relatively higher price of hermetic bags. Net benefit of investing in the technologies was estimated at US$ 28.05 million per season with tax. Without tax, demand was expected to more than double and the net benefits increase by 50%.

Cost benefit analysis (CBA) of hermetic bags for postharvest loss reduction of beans and cowpea was conducted in Benin (FANPRAN, 2017). The study found Benefit Cost Ratios of 7.41 and 5.6 respectively accruing from hermetic bags used for storing beans and cowpea respectively. A CBA of hermetic storage bags among smallholder maize farmers in Ethiopia showed that a change to Purdue improved crop storage (PICS) bags would highly increase gross margins (Alemu et al., 2021). In the study, partial budgeting was used to compare economic benefits from smallholder farmers who did not invest in storage technologies, those who invested in traditional storage technologies and finally investment in Purdue improved crop storage. However, partial budgets do not account for time value of money. Further, they are merely comparisons which do not estimate the absolute profitability of improved crop storage. The CBA is normally employed in economic evaluation of postharvest technologies.

Past studies reviewed were ex post evaluations. This is in line with the assertion by Kitinoja (2010), that for a long time, postharvest activities have not been given priority until recently, hence little emphasis on their ex-ante evaluation that finally led to low adoption levels. An ex-ante study of postharvest technologies in West and Central Africa employed the economic surplus model (ESM) to show the potential benefits arising from technological advancement (Moussa et al., 2011). To estimate the expected adoption rate of the postharvest technologies, the study followed the logistic growth model. Other studies rely on expert opinion to estimate this variable. Although there is no standard approach for estimating the expected adoption rate, the current study which also employed the ESM elicited this variable from the respondents. The respondents provided estimates of the proportion of their land that they were willing to allocate for PHLRTs annually. These estimates were more realistic and reliable.

In assessing WTP for PICS bags, Channa et al. (2019) used Becker-DeGroote-Marshack (BDM) auction to elicit demand. However, the auction approach failed to reveal the maximum WTP for the PICS hermetic storage bags. The authors found low awareness and low adoption of the technology. Farmers were willing to offer lower prices and demand increased with awareness. Demand was found to be highly elastic because farmers were not certain of the expected benefits. Factors influencing demand for PICS hermetic storage bags were estimated using the double hurdle model due to the presence of zero bids and the fact that different factors affect the decision to pay or not. The study found that prior awareness of the technology was statistically and economically significant in explaining demand.

In determining farmers' WTP for a postharvest cooling unit, Maalouf and Chalak (2019) employed CVM method. The WTP amount was elicited using different categories of price. By confining respondents to a range of prices, the study hindered respondents from revealing the highest amount they were willing to pay. The study reported that 80% of the respondents stated their WTP amounts. Since WTP amounts were reported on intervals, an interval regression model was employed to estimate factors influencing WTP amounts. Farming experience and access to wholesale markets, significantly affected WTP for the technology choice.

To estimate cocoa farmers' willingness to cushion themselves from postharvest losses in Ghana, Okoffo et al. (2016) employed the CVM method. Results showed that cocoa farmers in Ghana were willing to pay between GH¢49.32 and GH¢128.40 for every cost of production per acre. The double-hurdle model showed that socio economic characteristics such as age of the household head, marital status and level of education positively influenced farmer's willingness to pay for insurance while size of household and area under cocoa negatively influenced WTP for insurance. Factors that positively influenced the WTP amount were age of the household head, size of the household and area under cocoa. Marital status of the household head and income from cocoa negatively influenced the WTP amount.

To estimate determinants of WTP for a PHLRT, Bokusheva et al. (2012) used the double hurdle model. The authors found that age of household head, land tenure, access to extension services and infrastructure influenced demand. In estimating WTP for a maize PHLRT, Migwi et al. 2020 applied the contingent valuation method (CVM). Iterative bidding was employed to determine the maximum WTP amount. The authors found that the WTP amount was higher than the cost of the PHLRT in Nigeria. The Ordinary least square (OLS) regression model was employed to estimate determinants of WTP.

However, due to the presence of zeros in the dependent variable, the OLS estimates were biased. Awareness, access to credit, contract arrangement and initial bid amount positively influenced WTP for the technology.

The current study employed the CVM method in estimating WTP for PHLRTs. This is because these technologies are relatively new in the market. Iterative bidding was employed to elicit the upper limit of WTP amount for the technologies. Due to the presence of zeros in the dependent variable and cognizant of the fact that determinants of participation and expenditure decisions are different and emanate from two different choices, a double hurdle model was used to estimate determinants of WTP.

Dogan and Adanacioglu (2022) in estimating WTP for geographic indication labelled (GI-labelled) dried fruit pulp employed the CVM method. Dichotomous choice questions which were used failed to estimate the true WTP amount for GI-labelled dried fruit pulp. The WTP amount for GI-labelled dried fruit pulp was found to be lower than its market price range. The Tobit Model revealed that age, education, awareness of dried fruit pulp, consumption of GI – labelled products and price bids influenced demand of dried fruit pulp.

In estimating WTP for GI-labelled products, Dong (2019) used the CVM method and found that 33% of the respondents were willing to pay for GI vegetable and fruits, GI wine, Gi tea and GI Chinese herbal medicine. However, the study failed to determine a point estimate of WTP. The Tobit model revealed that WTP for GI vegetable and fruits was influenced by awareness of the products and income. Further, WTP for GI tea was found to be influenced by awareness and gender. Finally, WTP for GI Chinese herbal medicine was influenced by knowledge of GI, age and income. Employing CVM method, Gyan and Owusu (2017) analysed WTP for Moringa bread in Ghana using a double-bounded dichotomous choice framework. The authors found low WTP amounts for

Moringa bread. Ordered probit model showed that age of the household head, marital status, religion and the period consumers had used Moringa products were significant in explaining WTP.

CHAPTER THREE: GENERAL METHODOLOGY

3.1 Conceptual Framework

Appropriate policy environment enables investment in postharvest management research, adoption of good practices and facilitates coordination of value chain activities (such as securing contractual relations) (FAO, 2014b) in order to reduce postharvest losses. Household and farm characteristics influence access to extension services and producer awareness of PHLRTs Figure 3.1). Depending on product attributes, producers express their demand for these technologies. Adoption of the technologies lead to welfare gains to producers which determine the magnitude of the potential economic impact of investing in PHLRTs. Research on PHLRTs involve investment in knowledge diffusion for higher agricultural productivity and achievement of a range of economic and social objectives.

Agricultural research is mainly geared at enhancing economic efficiency, equity and security which lead to higher total income and improved income distribution (Alston et al., 1995; Batz et al., 2003). Contributions of research to security objectives involves calculation of how research reduces variability of agricultural income (Alston et al., 1995). Research ensures food and nutrition security, poverty alleviation, conservation of natural resources, and increased national self-reliance (Alston et al., 1995).

This study is mainly on the potential economic impact of research on PHLRTs. Role of research (such as that on PHLRTs) in enhancing economic efficiency and benefits distribution can be estimated as the NPV of shifts in economic surplus induced by research (Alston et al., 1995; Mujuka et al., 2017).

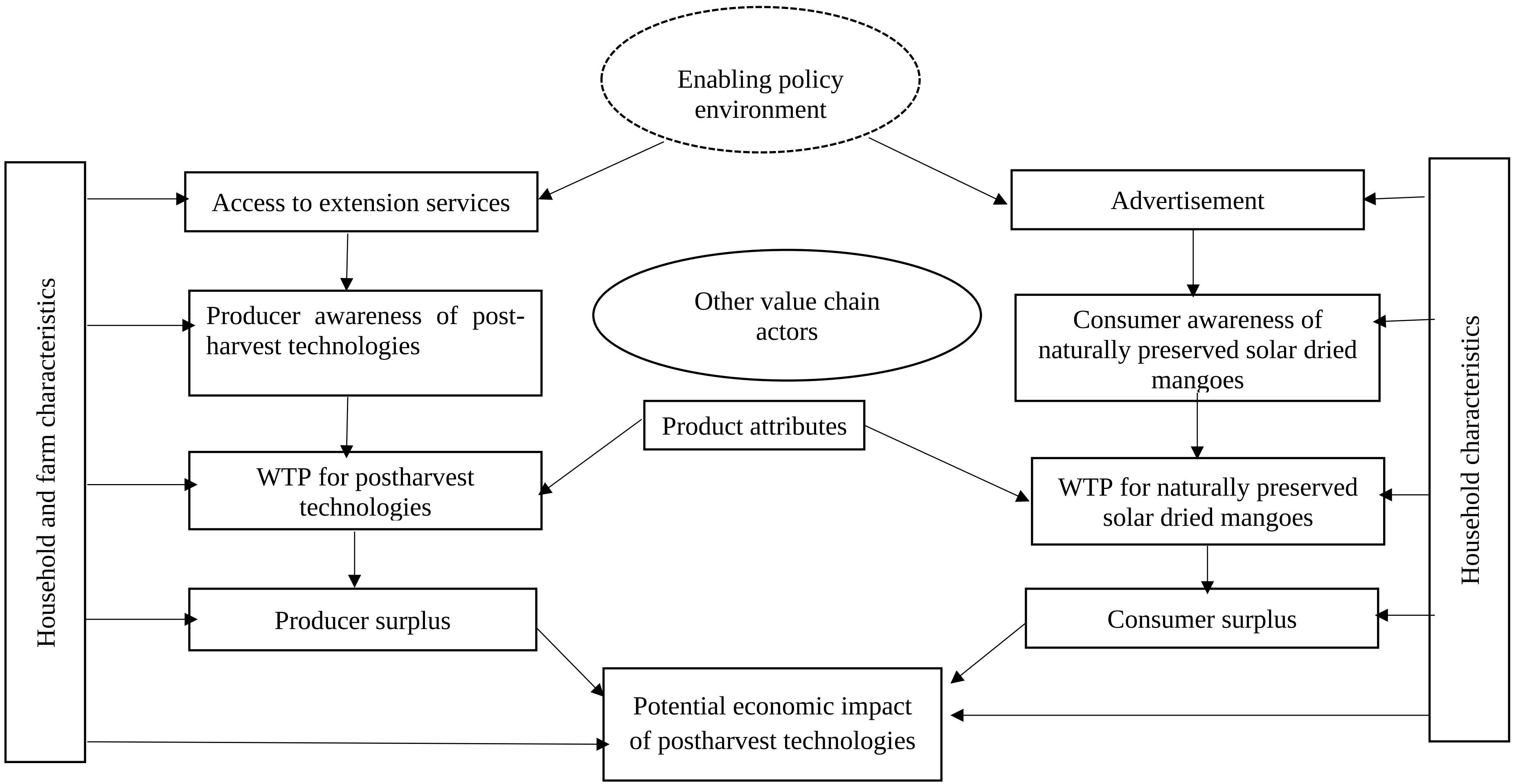

Figure 3.1: Conceptual framework of an analysis of the viability of PHLRTs along the mango value chain in Kenya (Source: Author)

These returns to research are not tenable if the proposed technologies are not accepted and adopted (Irungu, 2011; Mwaijande, 2017), prompting the need to assess farmer's willingness to pay for PHLRTs. Benefits spread geographically and vertically where goods and services are traded (Debass, 2000). Consumers depending on their household characteristics know of value-added products through advertisement in the mass media. Depending on the product attributes, consumers express demand for NPSDM. Consumer welfare gains expressed through the consumer surplus further contribute to the magnitude of the potential economic impact of investing in PHLRTs.

3.2 Research design

Quantitative and qualitative research designs were used in this study using both primary and secondary data. The primary data was collected through household and market surveys. For each objective, quantitative and qualitative approaches were used. To address the first objective, data was collected among household heads to identify the cost of current postharvest management strategies and how the proposed technologies would affect input costs. Further, information on household farm and socio-economic characteristics were used to estimate the ex-ante economic returns to investment in PHLRTs. Through the household survey, information on producer WTP for the PHLRTs and factors hypothesized to influence the WTP (objective 2) was collected. A scoping survey was conducted ahead of the market survey to identify the main retail outlets in Nairobi County specializing in wet and dried mango products. A market survey was then conducted to understand consumer awareness and WTP for NPSDM (objective 3). The study also collected data on factors expected to influence this WTP.

3.3 Sampling procedure

3.3.1 Sampling procedure for household survey

Multistage sampling was employed to determine samples in two purposively selected Counties. Specifically, the study was done in Masii and Mwala wards in Machakos County and Kyeni South ward in Embu County. Farmers in these two Counties had previously been trained on proper agronomy in order to reduce losses at the pre-harvest stage. The unit of analysis was the household. Systematic random sampling was employed to generate the sample from the sampling frame. The household was defined as either an individual or a group of people living together under the same roof. To achieve the first objective, a sample of 160 households were interviewed in Embu County following Cochran (1963). To achieve the second objective, a sample of 320 households was drawn from both Embu and Machakos Counties.

3.3.2 Sampling procedure for consumer survey

An accidental sampling procedure was employed in the consumer survey because the total population of consumers of fruit and/or processed fruit products was unknown. A total of 414 consumers were selected from Zucchini, Carrefour, Chandarana and Tuskys supermarkets which were found to be the main retail outlets selling fresh, wet and dried mango products from a scoping survey. Two of their busiest branches were selected. At the stores, consumers who either picked fresh fruits and/or processed fruit products were interviewed. To start with, the first consumer who picked either fresh fruit or processed fruit products was interviewed. After conducting the interview, the next consumer who picked either fruit or processed fruit products was interviewed. This cycle was repeated throughout the day.

3.4 Data collection and analysis

Some of the quality control measures employed in this study included training of enumerators, pretesting of data collection tools before collection of data, use of a reliable mobile data collection platform (Survey CTO) and cleaning of data. This involved follow up on missing data and removal of outliers. Household survey in both Counties was conducted between June - July 2018 from in-person interviews by enumerators who were trained using semi-structured questionnaire (Appendix 1). The household survey targeted heads of households. Key informant interviews to get expert opinion on the proposed technologies was conducted between May and December 2018 (Appendix 2).

The key informant interviews targeted researchers, scientists and extensionists from both private and public institutions. Secondary data necessary for the ESM was collected between August and December, 2018. The scoping survey which informed target retail outlets for the market survey was done between 10th and 16th July, 2019 in Nairobi County. The market survey was conducted between 8am and 8pm from Thursday, 30th January to Saturday, 1st February, 2020 (Appendix 3). Household survey data was analyzed using MS Excel 2016 for the ESM (Objective 1) and STATA version 14 for the double hurdle model (Objective 2). The consumer survey data was analyzed using STATA version 16 for the Tobit model (Objective 3).

CHAPTER 4: ASSESSMENT OF THE POTENTIAL ECONOMIC IMPACT OF POSTHARVEST TECHNOLOGIES AMONG SMALLHOLDER MANGO FARMERS[1]

4.1 Abstract

The horticultural potential in Kenya is hampered by significant PHLs ranging between 40% and 50%. The losses are driven by various factors including low adoption of PHLRTs and poor access to remunerative markets. Consequently, some farmer groups aggregate their mangoes and process them into shelf stable products which unfortunately are not marketable widely. To bridge the lack of capacity, the UoN through its postharvest project supported by the Rockefeller Foundation seeks to create awareness and provide applicable PHLRTs such as tunnel solar dryers, charcoal and zero energy brick coolers. However, little is known on the ex-ante economic return on investing in these technologies. Consequently, this study sought to assess the returns to investing in these technologies in Kenya. The ESM was employed in this study to assess the potential gains from the technologies. A Cost-Benefit Analysis of the postharvest project found that investing in the proposed PHLRTs is profitable. The NPV was estimated at US $ 1.3 billion. Sensitivity analysis revealed that the viability of investing in the proposed PHLRTs heavily depends on the adoption rate and cost of capital. Therefore, there is need to promote the adoption of the technologies and stabilize interest rates.

Keywords: Cost Benefit Analysis; economic surplus; internal rate of return; net present value; postharvest loss.

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[1] *Paper published as:* Mujuka, E., J. Mburu, A. Ogutu, and J. Ambuko. (2019). Returns to investment in postharvest loss reduction technologies among mango farmers in Embu County, Kenya. *Food and Energy Security* 9 (1). https://doi.org/10.1002/fes3.195

4.2 Introduction

4.2.1 Background

Postharvest loss reduction strategies offer unique income and food security opportunities for the over 200 million people that are food insecure in the sub-Saharan Africa (FAO, 2019b; Kikulwe et al., 2018). Historically, researchers interested in horticulture have focused on strategies for increased productivity of land (Kitinoja et al., 2011). The acreage under improved mango varieties has been increasing in response to demand (Snel et al., 2021). Up to 50% of horticultural produce are lost after harvesting in sub-Saharan Africa (FAO, 2019a). The perishability of fruits is higher than that of other crops, making them more susceptible to higher losses. With increased production, much higher postharvest losses are expected, if no postharvest measures are put in place.

The high PHLs occur due to low adoption of PHLRTs and poor access to remunerative markets. The current desperate trend in the management of fruit supply chains is attributable to poor government policies and lack of producer awareness of the need to reduce PHLs (Shukla & Jharkharia, 2013). To reduce PHLs, developing countries need to build the capacity of producers, improve infrastructure to ensure market access, develop value chains, improve postharvest technologies and collaboration between supply chains (Hodges et al., 2011). To reduce postharvest losses, harvesting should be done when it is colder during the day, produce kept under shade and protected from sunlight in the market (Kader, 2005).

In 2014, fruits in Kenya were valued at KES 51.4 billion, which domestically accounted for 26 percent of the horticultural produce value (HCDA, 2014). Fruit and vegetable sub-sectors befit smallholder farmers allowing them to actively participate due to the minimal required land and labour (Andrea, 2012). The mango (Mangifera indica, Linn) is the second important fruit (HCDA, 2014) with respect to production and acreage in Kenya and whose seed is a potential source of edible oils/fats (Muchiri et al., 2012). Mangoes in Kenya are produced in 10 main

Counties with Embu contributing 15% of the total production (HCDA, 2014). Kenya exports a paltry 2% of its national mango production. Between 2012 and 2013, mango exports grew by 141% earning KES. 1.4 billion ($14 million). Between 2013 and 2022 demand for mangoes is expected to double while export demand is expected to increase five-fold between 2011 and 2022 (USAID-KAVES, 2015).

Postharvest losses increase cost of managing waste and contribute to greenhouse gas emission, all of which are negative externalities to society (Aulakh & Regmi, 2013). Elimination of PHLs in fruits could increase the horticultural revenue of fruit traded locally by 17%. This could improve the positioning of the fruit sub-sector in relation to other horticultural sub-sectors that currently earn higher revenues. Reduction of these losses would increase food reserves while enhancing global food security (Kader, 2005) which is a concern with the high food prices occasioned by increased consumer demand.

The United Nation’s Sustainable Development Goal 12 (SDG 12.3) and the African Union Agenda 2063 are both committed to significantly reduce PHLs. Thus, efficiency and enhancement of food security is anticipated. A review of international development projects focusing on horticultural postharvest technologies in five countries including Kenya from 1996-2012, revealed that 83% of the projects were successful with barriers to adoption including high cost of initial investment, complex postharvest infrastructure, lack of awareness, group dynamics and limited market access (Kitinoja, 2010). Results of Cost-Benefit Analyses (CBA) of 30 commodity systems from 21 international horticultural postharvest technologies in 4 countries during 2009-2010, revealed that all the 21 postharvest technologies were profitable for smallholder farmers of which 81% increased returns by 30% or more (Kitinoja, 2013).

4.2.2 Role of postharvest loss-reduction technologies

In a given country, there exists a strong correlation between the extent of losses after harvest and both the technology that is available and the level of market development (Parfitt et al., 2010). Postharvest value addition technologies have potential to reduce postharvest losses hence provide high returns for farmers. Thus, developing cold chains is critical to ensure quality and safety (Kader, 2009). Hardly 20% of Kenyans (GoK, 2008) access electricity at the rural level. Further, most smallholder farmers cannot afford cold storage technologies that require electricity. This exacerbates smallholder farmers' exploitation by middlemen. Applicable and proven storage technologies such as brick and charcoal coolers can thus minimize postharvest losses thereby increase income of smallholder farmers (Jha, 2008).

Consequently, in Kenya, the UoN supported by the Rockefeller Foundation seeks to create awareness and provide applicable evaporative cooling technologies (Karithi, 2016; Shitanda et al. 2011) and solar dryers. Past international and national horticultural postharvest project interventions are rarely, if ever, re-evaluated once they are completed to determine whether the interventions promoted during the project increase welfare and are sustainable (Kitinoja, 2010). Therefore, little is known on the extent of their potential economic impact. This study attempted to address this knowledge gap by estimating welfare effects of investment in PHLRTs among mango farmers in Kenya. In agriculture, research is one of the several investment options available to governments and aid agencies across the globe. These agencies require concrete evidence of potential benefits associated with each investment alternative in research (Maredia et al., 2000). This information assists in planning for research, priority setting, guides adoption and investment decisions by farmers, donors and policy makers.

4.3 Methodology

4.3.1 Study Area

This study was carried out in Karurumo Location of Embu County. Embu County lies between latitude $0^0$8' and $0^0$50' South and longitude $37^0$3' and $37^0$9' East. The County rises from about 515m above sea level in the East to over 4,570m above sea level in the North West. The County has a total area of 2,818 sq. km. Embu County has various agro-ecological zones (AEZ) ranging from high altitude Lower Highland Zone one (LH1) to Upper Midland Zone four (UM4) (maize- sunflower zone). Others include the Lower Highland (LH0) which is the forest zone which is the same as Upper Highland (UH0) and are basically catchment areas.

The County receives short rains of between 1,200 to 1,850 mm received between the month of October and the month of December. Long rains of between 850 to 1,850 mm are received between March and June. The County's temperatures range from 12^0C in July to 30^0C in March with a mean average of 21^0C. Higher parts of the County are too cold with soils which vary in fertility and depth (Histosols and Leptosols). At slightly lower altitude are humid top soils of moderate fertility (Andosols) which are leached and acidic. Most parts of the County forming volcanic ridges have moderate to high fertility soils (mainly Nitisols and Andosols) with top soils which are often rich in organic matter. The lower part of the County has deeply weathered red clay soils (Ferralsols) whose fertility is low.

The County has a population of over 608,599 persons and a population density of 216 people per km^2 (KNBS, 2019a). Agriculture is the mainstay of the County and livelihood of the people of Embu. Major enterprises in Embu are tea, millet, coffee, cassava, dairy. fruits and vegetables. Embu County is suitable for mango production because the crop does well in low land to upper midland areas. About 1600 Ha are under mangoes in the County with an average production of 29,084 MT in 2019 (HCD, 2020). Over 20% of the farming households in the

County produce Mangoes (KNBS, 2019b). Mango has maintained an upward production trend. However, in 2020 the output declined by 38% due to the mango fruit fly. Mango production is the mainstay for farmers in Embu and controls about 40% of the household income.

4.3.2 Sampling and Data Collection

The multistage sampling procedure was used to sample 160 farmers based on Cochran (1963). Accordingly, $n = (Z^2pq)/e^2$

Where;

n = Sample size

Z = Standard normal deviate at the selected confidence level. (The value of Z is 1.96 for the commonly preferred 95% confidence interval)

p = Proportion in the target population estimated to have characteristics being measured (proportion of farmers producing mangoes in Karurumo Location)

$q = 1 – p$

e = Desired level of precision (5% to 10%)

Thus, $n = 1.96^2 \times 0.88 \times 0.12/ (0.05)^2 = 160$. Purposive selection of Embu County was done because previously farmers in the County had been trained on preharvest loss reduction. A household survey was conducted to obtain data on socioeconomic characteristics of households, extent of postharvest losses, cost of current mitigation strategies and willingness to pay for the proposed PHLRTs. The quantity of mangoes that farmers were willing to handle in the tunnel solar dryers, charcoal and brick coolers over a period of 10 years indicated the adoption lag, the expected adoption rate and the number of years to maximum adoption. Expert opinion on expected yield increases, success and depreciation rates was sought from researchers, scientists and extensionists. According to expert opinion the PHLRTs would increase yield by 40% on average. A conservative maximum adoption rate of 10% was assumed. Price elasticities of supply and demand and discount rate were obtained from secondary data. The research activities would culminate in extension activities that would create awareness on the PHLRTs among smallholder farmers.

4.3.3 Methods of data analysis

Returns to investment in agricultural technologies can be evaluated using several approaches. These include the scoring models, mathematical programming, simulation models and cost-benefit analysis (Braunschweig, 2000). Scoring models involve ranking of alternatives based on weighted research objectives. This ordinal ranking is the basis for resource allocation decisions, and the research alternatives are funded based on their ranking. These models are simple and allow multiple objectives to be incorporated. They however lack sound theoretical framework, are costly and consume a lot of time. Mathematical programming is a technique which guides the optimal distribution of limited resources (Marconil et al., 2015). Unlike scoring which only ranks alternatives, mathematical programming identifies optimal research portfolios. Mathematical programming techniques can accommodate different funding levels for each activity. However, the technique requires knowledge on the functional relationship between the funding level and the expected benefits. Programming methods are also time consuming.

Simulation models are based on principles of production economics (Antle et al., 2015). They estimate the functional relationship between input (research investments) and agricultural output. Simulation models are generally employed at higher aggregated level. For instance, a production function may be identified to represent the econometric relationship between agricultural productivity on the one hand, research (and extension) expenditures and other determinants on the other. Then, the effect of research expenditure on productivity are simulated. The resulting changes on productivity are then demonstrated through a supply curve shift which illustrates economic consequences. Mathematical relationships necessary to build the model need to be determined. Analysis of econometric relationships rely on time-series data, which were not available in the case of PHLRTs.

Cost-benefit analysis approach employs the concept of economic surpluses. The ESM developed by Alston et al. (1995) is anchored on the need for efficient allocation of scarce resources for agricultural research and is anchored on welfare economics. Accordingly, a change in policy is desirable if the change can make both consumers and producers better off. The model measures benefit to consumers and producers as net change in consumer and producer surplus. These gains are then compared to research cost to determine the aggregate social net benefit of research. The main drawback of the ESM is the assumption that the commodity market is static. This assumption ignores other dynamics which may affect the benefits of a given intervention. Nonetheless, the ESM has been employed widely to assess the impact of novel agricultural technologies (Kassie et al. 2018a; Mujuka et al. 2017) and was used in this study. A static partial-equilibrium ESM (Kristjanson & Zerbini, 1999) was adopted. Potential benefits of investing in PHLRTs were estimated using the change of economic surplus and the Net Present Value (NPV) was calculated using a discount rate of 10% in 2019 dollars.

4.3.4 Conceptualizing economic surplus modeling in a closed economy

The ESM is based on the interaction between supply and demand resulting in equilibrium quantity and price. Producers' production costs are represented by the supply curve while consumer consumption values are represented by the demand curve. Economic welfare gains due to research arise from producers earning more than the marginal costs they incur and consumers' WTP more than the market price (Figure 4.1). Since few mangoes from Kenya are traded internationally, a closed economy model was assumed. The adoption of a yield-increasing PHLRT may reduce prices. Thus, consumers gain through cheaper access to mangoes while producers increase supplies and benefit from economies of scale. Parallel shifting simple linear supply and demand curves were adopted (Kristjanson & Zerbini, 1999).

Figure 1 shows a basic ESM for estimating potential benefits of PHLRTs where; D denotes the demand function for mangoes, while S_0 and S_1 are the supply functions for mangoes before and after investment in PHLRTs, respectively. P_0 represents the price before the research induced shift while P_1 is the price after the shift. Q_0 and Q_1 are the equilibrium quantities before and after the changes induced by research.

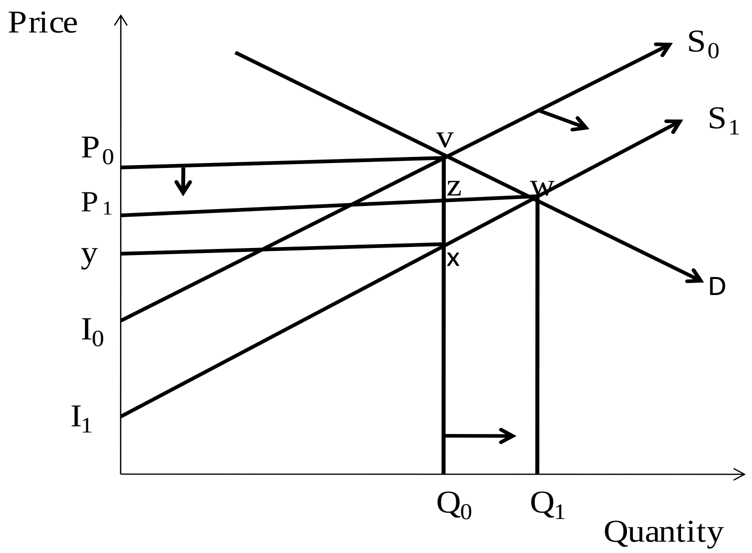

Figure 4. 1: Estimating potential benefits of PHLRTs

Source: Adopted from Alston et al., (1995)

Change in consumer surplus is represented by the area P_0vwP_1 while change in producer surplus is represented by the area P_1wxy. The change in total surplus (P_OvwP_1 + P_1wxy) is represented by the area I_0vwI_1. Without PHLRTs, this surplus would not be realized**.** Before adoption of PHLRTs, Q_0 of mangoes is demanded at price, P_0. Thus, point v is the equilibrium point with P_0 showing the equilibrium price and Q_0 showing the equilibrium quantity.

After adoption of PHLRTs, the supply curve shifts from S_0 to S_1, hence P_1 is the new equilibrium price and Q_1 is the new equilibrium quantity. Gross returns to research are estimated by the area under the demand curve and between the two supply curves (I_0vwI_1). This is the change in total surplus and the potential benefit of investing in PHLRTs. Producer surplus which is a measure of producer welfare is the difference between the price that producers are willing and able to sell their produce and the market price, while consumer surplus (CS) is the gain to consumers when they pay for a commodity or service at a price that is lower than the market price (Ashok et al., 2017). Change in PS and CS largely depend on price elasticities of supply and demand (Kassie, 2018b).

4.3.5 Data needs, sources and analysis

Parameters needed for estimation of the surpluses are shown in Table 4.1, where K is the shift of the supply curve, η is the absolute value of the elasticity of demand, ε is the elasticity of supply, $Z = K\varepsilon / (\varepsilon + \eta)$ is the reduction in price, p is the success rate and assumed to be 1 and δ is the reduction of expected yield and was assumed to be 0. Different sources of these parameters have been specified. Descriptive statistics were generated using STATA Version 14. The cost benefit analysis was performed using the EXCEL spreadsheet. The spreadsheet was used to show the sensitivity of the results to changes in discount rates and adoption levels.

Table 4.1: Variables used in the economic surplus model

Parameters	Formula/Symbol		Source
Price elasticity of supply	ε	0.74	Alston et al., (1995) Giblin & Mathews, (2005)
Price elasticity of demand	η	0.58	Bundi et al., (2013) Ecker & Qaim, (2008)
Proportionate increase in yield (%)	$E(Y) = (Y_1 - Y_0)/Y_0$	10	Expert opinion (Conservative estimate)
Cost reduction (%)	$E(C)$	121	Own calculation
Net reduction in cost (%)	$K = \left[\frac{E(Y)}{\varepsilon} - \frac{E(C)}{1 + E(Y)}\right] p A_t (1 - \delta_t)$	-8.79	Own calculation
Adoption rate	A_t	0.45	Mean of annual proportion of mangoes farmers who were willing to manage PHLs through the PHLRTs
Relative reduction in price (%)	$Z = K\,\varepsilon / (\varepsilon + \eta)$	-4.93	Own calculation
Initial equilibrium price (USD)	P_0	150	Survey data
Yield (before research induced change) (Tons)	Y_0	23.24	Survey data
Yield (after research induced change) (Tons)	Y_1	25.56	Expert opinion

Change in consumer surplus (M) USD/Hectare (Ha)	$Z P_0 Y_0 [1 + (0.5Z\eta)]$	639	Own calculation
Change in producer surplus (M) USD/Ha	$(K\text{-}Z) P_0 Y_0 [1 + (0.5Z\eta)]$	500	Own calculation
Change in total surplus (M) USD/Ha)	$\mathbf{K P_0 Y_0 [1 + (0.5Z\eta)]}$	**1139**	**Own calculation**

Source: Adapted from Kristjanson & Zerbini (1999), Alston et al. (1995) and Survey data (2018)

4.4. Results and Discussion

4.4.1 Descriptive Statistics

Results revealed that most (84%) of the household heads were males aged 58 years on average with 11 years of experience in mango production (Table 4.2). Ageing male farmers have more experience (Abdulai & Huffman, 2005) and are more resource endowed (Kaliba et al. 2000) due to their higher chances of accessing capital. Results reveal that 8% of the respondents had access to credit. The respondents were relatively literate, having spent an average of 8 years pursuing formal education. The cognitive ability of literate farmers is higher. They also have higher access to information and higher chances of adopting technologies with potential for higher economic benefits. This is shown by the high level of awareness on PHLRTs (62%) and further supported by the high access to agricultural extension services (43%). This explains the respondents' willingness to pay for PHLRTs.

Table 4. 2: Summary of socio-economic characteristics of respondents

Explanatory variable (n=160)	Mean	Std. Deviation
Gender of Household Head (% Males)	0.84	0.36
Age (years)	58.09	14.71
Experience (Years)	10.92	6.90
Access to credit (% Yes)	0.08	0.26
Education of household head (Years)	8.13	4.12
Total land size (acres)	3.16	3.90
Area under mangoes (acres)	0.66	1.47
Aware of PHLRTs (% Yes)	0.62	0.49
Access to extension services (% Yes)	0.43	0.50
Group membership (% Yes)	0.22	0.42
Willingness to pay for a charcoal cooler (% Yes)	0.71	0.45
Willingness to pay for a brick cooler (% Yes)	0.50	0.50
Willingness to pay for a tunnel solar dryer (% Yes)	0.48	0.50

Source: Survey Data (2018)

Agricultural groups are social network platforms through which farmers learn about new technologies such as PHLRTs. Out of the sample, 22% of the farmers belonged to agricultural groups.

Results revealed that between 50% and 71% of the farmers were willing to pay for the evaporative cooling technologies and about 48% of them were willing to pay for tunnel solar dryers. These results indicate acceptability of PHLRTs and are further supported by findings of Ogumo et al. (2017) who estimated the rate of adoption of charcoal coolers at 80% in Kajiado and Narok Counties in Kenya. This is attributable to the low payback period estimated for horticulture evaporative coolers (Tilahun, 2010).

4.4.2 Deterministic cost-benefit analysis

Evaporative cooling technologies are not new worldwide but their use in Kenya is limited. Therefore, cost of research was not factored in the analysis, following Karl et al., (2012). The extension activities throughout the adoption period were estimated at the cost of US$ 5 per farmer per year (Perraton et al., 1983). This cost was added annually to the cost of installing a 4M X 4M X 2.5M charcoal cooler, a 3M X 2M X 1M zero energy cooler and a tunnel solar dryer of 17M X 1.5M X 1M.

Farmers provided data on the number of mangoes that they were willing to handle in the PHLRTs for a period of 10 years from 2019. This proportion out of their total output was assumed to be the adoption rate and was calculated annually. The average adoption rate was estimated at 45%. However, a conservative cumulative adoption rate of 10% was assumed starting with 1% adoption in year one. The total cost of the structures was approximated based on the corresponding expected adoption rates. There was no adoption lag as no farmer was not willing to store mangoes in 2019. Farmers were expected to start benefiting from PHLRTs from 2019. The change in total surplus over a period of 10 years formed the benefit stream. These potential benefits were then discounted at 10% (the lending rate for agricultural loans) per annum and compared against discounted cost of the technologies and extension. Investment methods such as the NPV were employed to estimate the economic feasibility of investing in PHLRTs.

According to Affognon (2010) a social discount rate ranging between 8-12% per annum is credible. In 2019, the Agricultural Finance Corporation (AFC) offered agricultural loans at an interest rate of 10%. The NPV of investing in PHLRTs was estimated at US $ 1.29 billion, the

IRR was 28% while the BCR was 4:1 (Table 4.3). The positive NPV imply that the proposed investment in PHLRTs is viable. This is also supported by the IRR of 28% which is higher than the cost of capital. A BCR of 4:1 implies that investors expect a benefit of $ 4 for every $ 1 spent. Investing in PHLRTs is thus worthwhile.

These results concur with Moussa et al. (2011) who evaluated the economic impact of improved cowpea PHLRTs in West and Central Africa and found that recipient countries found the project viable since the regional IRR estimated at 29% surpassed the cost of capital. According to the US government which was the principal donor, the project was worth investing in. The NPV was greater than 295 million US dollars valued at about 17 million US dollars annually. Further, in assessing the return on investing in improved post-harvest technologies, Mwebaze & Mugisha (2011) estimated the BCR at between 4.3 - 5.5 further supporting the assertion that investment in PHLRTs is viable.

Table 4. 3: Cost Benefit Analysis results of investing in PHLRTs in Kenya

Period	Costs (US$)	Benefits (US$)	Discounted Costs (US$)	Discounted benefits (US$)	Cumulative net Discounted Benefits (US$)
2019	10,872,012	-133,199,198	9,893,531	-121,211,270	-131,104,801
2020	22,613,784	-225,146,559	18,769,441	-186,871,644	-205,641,085
2021	35,277,504	-263,384,217	26,458,128	-197,538,163	-223,996,291
2022	48,918,139	-233,324,654	33,264,334	-158,660,764	-191,925,099
2023	63,593,580	-117,957,646	39,428,020	-73,133,741	-112,561,760
2024	79,364,788	102,478,595	44,444,281	57,388,013	12,943,732
2025	96,295,943	450,866,177	49,110,931	229,941,750	180,830,819
2026	114,454,606	953,620,651	53,793,665	448,201,706	394,408,041
2027	133,911,889	1,641,153,500	56,242,994	689,284,470	633,041,477
2028	154,742,628	2,548,389,491	60,349,625	993,871,902	933,522,277

Net Present Value = US$ 1,289,517,310 Internal Rate of Return = 28% Benefit Cost Ratio = 4.29

Similarly, Kimenju & De Groote (2010) provided evidence that investing in maize PHLRTs in Kenya is viable. The authors found that the NPV for the four new maize postharvest technologies were USD 2,060, 2,111, 1,828 and 2,216 with Benefit Cost Ratios (BCR) of 7.1, 3.2, 0.5 and 3.0, respectively. In addition, Regassa (2014) evaluated the ex-ante benefits of reduction of postharvest maize losses in Darimu Woreda, Ethiopia. The NPV of the project was found to be USD 36.4M. The IRR was 250% and the BCR was estimated at 253. These results demonstrate that investments in PHLRTs pay off.

4.4.3 Sensitivity analysis

Our analysis attempted to estimate the returns to investment in PHLRTs assuming certainty of adoption profile, costs and benefits to potential adopters. This is not always the case in the real world. In order to take care of uncertainty, sensitivity analyses were conducted through varying adoption and interest rates. Increasing the adoption rate to 12% the NPV increased to $ 4.58 billion and the IRR and BCR doubled to 58% and 9.4, respectively. Reducing the interest rate to 8% increased the NPV to $ 1.61 billion. Further, increasing the interest rate to 12% reduced the NPV to $ 993 million and the BCR to 3.9. The results displayed sensitivity to changes in the adoption and interest rates.

Attractive results were displayed at higher adoption rates and lower discount rates. This implies that returns to PHLRTs heavily depends on adoption rates. These results as expected, show that investment in PHLRTs is worthwhile at lower discount rates. The cost of capital is affordable at lower discount rates and this is essential for higher benefits to be realized from investment in the proposed technologies.

CHAPTER 5: ANALYSIS OF FARMERS' WTP FOR POSTHARVEST LOSS REDUCTION TECHNOLOGIES AMONG SMALLHOLDER MANGO FARMERS[2]

5.1 Abstract

Postharvest reduction has been recognized as a sustainable alternative for ensuring global food security. At least 40% of the harvested fruits fail to reach the consumer due to postharvest losses. Reducing these losses requires use of acceptable PHLRTs. Consequently, this study assessed the acceptability of evaporative cooling technologies and solar dryers in Kenya. Multistage sampling was employed in selecting 320 smallholder farmers in Embu and Machakos Counties. Factors conditioning WTP for the PHLRTs was estimated using a double hurdle model. Awareness and access to extension on the technologies were found to be low. The farmers' probability to pay and WTP amounts were significantly and positively influenced by factors such as initial bid in eliciting WTP, belonging to an agricultural group and mango income. Another significant factor was gender, which negatively and positively influenced the probability to pay in Embu and Machakos, respectively. However, experience in mango farming, age, credit access, market access and type of land tenure negatively influenced the WTP amount. Results revealed that the WTP for the PHLRTs were lower than the market prices. Thus, the government should spur demand through enhanced extension programmes and short-term price subsidies.

Keywords: WTP, postharvest loss, postharvest technology, double hurdle, Kenya.

5.2 Introduction

[2] *Revised paper submitted to the Food Security journal as:* Mujuka, E., J. Mburu, A. Ogutu, and J. Ambuko. Willingness to pay for postharvest technologies and its influencing factors among smallholder mango farmers in Kenya

A key global policy challenge is ensuring food security for the expected population of almost 10 billion people in 2050 (FAO, 2020). Agricultural research has historically focused on increasing productivity with little emphasis on minimization of PHLs. Globally, annual PHLs are estimated at US$ 1 trillion (FA0, 2015). In the recent past, several studies have highlighted FAO's methodological challenges and proposed improved methods in the estimation of postharvest losses across the globe (Aragie et al., 2018; Reynolds et al., 2019).

Studies conducted in the sub-Saharan Africa estimate postharvest losses in mangoes at 25% - 56% (Affognon et al., 2015). This is the case despite the high incidences of food insecurity that are expected to rise with population growth. Postharvest losses are higher in horticulture due to their perishability. Lack of PHLRTs and poor infrastructure lead to quantitative and qualitative postharvest losses at all stages of horticultural supply chains in Kenya (FAO, 2014a). Most of the world's population growth is expected from SSA where about 200 million people are food insecure.

In Kenya, fruits are valued at about KES 60.7 billion (USD 0.6 billion) and domestically this accounts for about 26 percent of the value of horticultural produce (HCD, 2017). The horticultural sector is considered befitting to smallholder farmers since the required land and labor are low (Andrea, 2012). According to FAO (2017), the prevalence of undernourishment over the period 2014-2016 was approximately 20% of the total population in Kenya. With respect to production and acreage, the mango (Mangifera indica, Linn) is the second largest fruit after the banana (HCD, 2020). Mango is rich in thiamine, niacin, calcium, iron and the protein content in it surpasses that in all other fruits except avocado (Griesburg, 2003).

Mango prices vary based on varieties. Improved mango varieties are sold at an average farm gate price of KES 25 (USD 0.25) per kg (Musyoka et al., 2020). At low farm gate prices, middlemen maximize their profits by higher margins. This relegates mango farmers to mere price takers due to their lack of capacity to store and process their mangoes for extended shelf life and higher margins. Most of the fresh mangoes in Kenya (about 99% of the total mango production amounting to approximately 695,888 MT) are sold domestically, while the export market accounts for a meagre 1% that is valued at approximately KES 1.4 billion (USD 14 million) per year (HCD, 2017).

Investment in PHLRTs was found to be a cost-effective pathway for ensuring food and nutritional security in Egypt, Indonesia, Kenya, Ghana and India (Kitinoja, 2013). A study on the viability of PHLRTs in Kenya, found that investment in the proposed technologies is worthwhile (Mujuka et al., 2019). The NPV, IRR and BCR were estimated at US $ 1.3 billion., 28% and 4.29, respectively. Further, PHLRTs eliminate wastage of scarce resources through the saved food (GIZ, 2013). According to the FAO and the World Bank, the postharvest sector requires about USD 470 billion which is half of the amount required to eradicate hunger in SSA.

Resolute efforts to halve the postharvest losses have also been demonstrated by the United Nation's Sustainable Development Goal (SDG 12.3) and the African Union Agenda 2063. Simple and effective evaporative cooling technologies (Shitanda et al. 2011) such as zero-energy brick coolers and charcoal coolers can thus be used to minimize postharvest losses in fruits and vegetables thereby improving farm incomes. Solar dryers reduce postharvest losses through drying of fruits and vegetables into more shelf stable products such as mango leather and mango crisps (Steve,2010) which fetch higher prices than the equivalent quantities of fresh mango fruits. For instance, the average farm gate price of a kilogram of fresh mango fruit in Kenya and Ghana is USD 0.3 while the average price of mango crisps in Kenya and Ghana is USD 7 and USD 20 (Adams et al., 2019; Musyoka et al., 2020).

Charcoal coolers and zero energy brick coolers are off-grid evaporative cooling technologies which are appropriate for smallholder farmers without access to electricity (Ambuko et al., 2017). Further, they are constructed from locally available materials making them accessible to resource-poor smallholder farmers. Evaporative cooling is appropriate for minimization of postharvest losses in horticulture at collection points and at the retail level. Solar dryers rely on direct sun radiation and work based on the resulting greenhouse effect. They have three main components which are; a drying chamber for drying food, a solar collector that heats the air, and an airflow system. Solar dryers can dry horticultural produce increasing shelf life by up to one year. Globally, these technologies are not new but their adoption is limited in Kenya.

A number of initiatives such as the UoN's postharvest project seek to create awareness and provide these technologies to smallholder farmers in Embu and Machakos Counties. Farmers in these Counties had previously been trained on the reduction of preharvest losses (RF, 2020). Pre-harvest practices determine quality of fruit at harvest and how long the produce stays after harvesting (Bundi et al., 2020). The acceptability as well as farmers' adoption capacity of PHLRTs is not known. Therefore, this study sought to estimate the mean WTP and the influencing factors in order to demonstrate the acceptability of the PHLRTs and guide pricing decisions and product development.

5.2.1 Approaches in estimation of willingness to pay

Estimation of WTP can be through the indirect and direct approaches. The indirect approach examines real-world choices that occurred previously and involve trade-offs between cost and expected outcomes while the direct approach involves survey methods which elicit statement of monetary values for non-traded commodities and services (O'Brien and Viramontes, 1994). The indirect approach relies on data collected on observed behavior while the direct approach involves interviewing individuals to establish the value one is willing to pay for a hypothetical good (Whittington et al., 1990). The direct approach is known as contingent valuation method

(CVM). It is “contingent” since it involves the researcher providing a hypothetical good or service (Arrow et al. 1993) with the purpose of eliciting individual’s WTP. The CVM was employed in this study.

The CVM has been widely employed by economists in valuing changes in natural resources and environment. Further CVM has been widely employed in eliciting farmers’ WTP for attributes of crops and other technical innovations, mainly where revealed preference approaches are not feasible (Chia et al., 2020; Kahwai et al., 2021; Shee et al., 2020). These studies have demonstrated that there is WTP for new technologies with potential to reduce PHLs among farmers.

5.2.2 Contingent Valuation Method

The CVM is a value elicitation approach that is survey-based and involves systematically interviewing respondents in order to assess their WTP for a new policy or development intervention (Kwak et al., 2013). Goods and services are evaluated by respondents based on added value or effectiveness (Mwaura et al., 2010). This involves presenting the respondent with one or a number of prices which they can choose or refuse to accept, thus generating interval data on WTP (Fernandez et al., 2004). The CVM was employed in this study because it involves a hypothetical market transaction for which there is need to elicit individual’s WTP. The advantages of CVM over indirect methods are twofold. First, it allows both use and non-use values while apart from involving weak complementarity assumptions, the indirect methods only cover use value. Secondly, CVM addresses WTP or willingness to accept (WTA) questions through theoretically sound monetary measures of utility change unlike the indirect methods (Perman et al., 2003).

Estimates of WTP largely depend on how the WTP amount is elicited (Umberger et al., 2009). There are different methods of eliciting WTP including open ended format through which the respondent provides a point estimate of their WTP; Dichotomous or Discrete Choice CVM through which stylized questions are asked to respondents who simply answer with a yes or no; payment cards through which respondents choose a WTP point estimate from a list of values displayed on a card and lastly bidding games that to start with, involve inquiring from respondents whether they would accept an initial bid price for the commodity. For the latter, the initial bid price is increased or decreased depending on the responses, with bidding process stopping at the point of convergence which is a point estimate of WTP (Haab and McConnell, 2002).

Bidding game ensures respondents carefully consider their options before stating the amount they are willing to pay (Willis, 2002). However, it is susceptible to 'Yea saying', which is a type of bias that occurs when a respondent replies 'yes' to the WTP question whether or not they are actually willing to pay (Ready et al., 1996). This would amount to inflated mean WTP estimates (Ternent and Tsuchiya, 2013). Starting point bias among individuals without definite preferences for the good or service and consequently no definite idea of their maximum WTP, may find the initial bid suggestive of the true value of the respective good or service (Whitehead, 2002).

According to Boyle et al. (1988) between iterative bidding, payment cards and dichotomous cards (DC) none is a superior value elicitation method. Consequently, the current study used iterative bidding games. Further, there is evidence that they capture the upper limit of the price that respondents are willing to pay (Wattage, 2002) thus measure the complete consumer surplus (Cummings et al., 1986). The monotonous small regular increment of the amounts offers the respondent leeway to turn down the bid amount contrary to a double-bound DC format where the bids are doubled or halved (Venkatachalam, 2004). To get realistic WTP estimates, the proposed technologies were clearly described to the respondent (Bateman et al., 2002).

5.2.3 Theoretical Framework

The random utility model (RUM) underpins the concept of WTP. The total amount of money that people are willing to give up (WTP) (Arrow et al. 1993) for postharvest storage technologies subject to the expected utility can be computed to derive the compensated market demand for these interventions in order to detect the point on the demand curve that maximizes profit that often is not essentially the mean value. The amount a consumer is willing to pay is pegged on their expected utility (Herriges et al., 2004). The highest WTP amount expresses the value an individual attaches to a good or service (Herriges et al., 2004).

Assuming that the utility derived from PHLRTs is given as Uiq, a mango farmer will decide on whether or not to pay for PHLRTs based on the utility associated with the two choices. The probability that PHLRT will be chosen is given by

$$P(y_i = q)\, p\big(U_{iq} \geq U_{ir} \setminus X, \emptyset\, r = q\big) = P(\mathcal{E}_{iq}\text{-}\mathcal{E}_{ir}) \leq X_{iq}{}'\beta_q - X_{iq}{}'\beta_r \setminus X, \emptyset\, r \neq q \quad (1)$$

Where y_i is the observed outcome for the i^{th} observation, i=1 ….. N indexes the mango farmer, q=1 and r =1….r are the alternatives under consideration and $\mathcal{E}$ are the random errors. The difference in the utilities, Vi of adoption and non-adoption are unobserved,

$$Vi = Uiq - Uir \qquad (2)$$

The household decision is taken as a binary outcome such that

$$q_i \in q = \{1\, if\, V > 0, 0\, if\, V \leq 0\} \qquad (3)$$

Since utility is unobservable, choices are based on preferences and what is not chosen is influenced by random factors (McFadden, 1974). Producers' WTP for non-market goods has been demonstrated to be significantly lower than current technology prices (Atreya, 2007; Hudson and Hite, 2003). Extensive economic literature (Chia et al. 2020; Kahwai et al. 2021;

Maalouf and Chalak, 2019) highlight factors that influence WTP, some of which are relevant to this study.

5.2.4 Empirical model

With two binary equations, it is not possible to employ the conventional probit or logit models (Asmare et al., 2022). The double hurdle model decomposes producer behaviour into two parts by first determining reasons for WTP for PHLRTs (first hurdle) and secondly determining reasons for the stated WTP amounts (Dalmau-Matarrodona, 2001). The main advantage of the double-hurdle model is that the first hurdle not only determines the socioeconomic characteristics of the respondents who are not willing to pay for PHLRTs, but it also defines the WTP equation better (Jones, 1989).

The first hurdle relating to the WTP for PHLRTs was modelled as a probit regression as follows:

$$w* = v_i'\alpha + \varepsilon_i \qquad (4)$$

$$w_i = 1 \text{ if } w_1{}^* > 0 \text{ and } w_i = 0, \text{ if } w_1{}^* \leq 0 \qquad (5)$$

$w*$ is a latent variable representing WTP for PHLRTs which assumes a value of 1 and 0 otherwise, v is a vector of non-linear variables that explain the WTP decision. α represents a vector of parameters and $\varepsilon_i$is the error term assumed to be independent with a normal distribution and constant variance.

The second hurdle which relates to the WTP amount is a truncated regression (at zero) and which is expressed as:

$$w_{amt} = m_i'\beta + \mu_i \qquad (6)$$

$$w_{amti} = w_{amt} * if\ w_{amt} *> 0\ and\ w_{amt} * = 0\ if\ otherwise \qquad (7)$$

w_{amt} is the observed WTP amount for PHLRTs, m is a vector of variables explaining the WTP amount, β is a vector of parameters and $\mu_i$is the randomly distributed error term.

5.3 Methodology

5.3.1 Study Area

This study was carried out at Karurumo and Masii Locations of Embu and Machakos Counties, respectively. Machakos borders Nairobi to the West and Embu to the North. Machakos lies between latitudes 0º45´South and 1º31´South and longitudes 36º45´ East and 37º45´ East at an altitude of 1000 to 2100 metres above sea level. The area of the County is 6,208.2 km² and it has five agro-ecological zones (AEZs). These include the Lower Midland Zone three (LM3) which suits production of mangoes. This AEZ is found in Kangundo, Kathiani, Mwala, Yatta, Matungulu, and Masinga Sub-counties. This study was conducted in Mwala sub-county. Other AEZs include LM4, LM5 (both of which are suitable for mango production) UM 2-3 and UM 5-6.

The County receives short rains in October and December while the long rains are received from March to May. The rainfall range is between 500mm and 1250mm. Rain in the County is not evenly distributed and it is unreliable. Temperatures range between 18˚C and 29˚C with an average annual humidity of 72%. There are five main types of soil in the County, namely; alfisols, acrisols, ferrasols, vertisols and andasols. The alfisols and acrisols are classified as sandy loams to loamy sands and are the predominant soil types in the County. They are brown to reddish brown, unfertile, have high erodability and they form hard pans.

The county has a population of over 1,421,932 whose population density is 235 people per Km^2 (KNBS, 2019a). Agriculture is the mainstay of the County which is largely semi-arid. Horticultural produce such as mangoes, maize, sorghum and millet do well in the County. The area under mango has been on the rise. However, the area in 2020 declined by 59% from 2019 (HCD, 2020). Over 33% of the farming households in the County produce Mangoes (KNBS, 2019b). The total production of mangoes in 2020 was 21, 655MT. Mango production contributes about 40 percent of the farm household income. Both Embu and Machakos

Counties are suitable for mango production and the crop contributes significantly to the farm household income in both Counties. In 2019, the two Counties contributed about 20% of the total mango produced in Kenya (HCD, 2020).

5.3.2 Sampling procedure and data collection

Multistage sampling procedure was employed to determine samples in two purposively selected Counties where farmers had previously been trained on proper agronomy in order to reduce losses at the pre-harvest stage. Households were selected through systematic random sampling. Specifically, the study was conducted in Masii and Mwala wards in Machakos County and Kyeni South ward in Embu County. These Counties are also among the main mango producing areas in the country. The sample size was determined following Yamane (1967). Accordingly,

$$n = \frac{N}{1 + N(e^2)}$$

Where;

n = Sample size,

N = Population size,

e = The desired level of precision (5%)

$$n = \frac{16,550}{1 + 16,550\ (0.05)^2}$$

$$= 391$$

Following Mujuka et al. (2017) who estimated the economic feasibility of investment in integrated pest management in horticulture using a sample size of 200 farmers and due to budgetary constraints, a sample of 320 households was interviewed in this study. Proportionate to size criteria was employed to determine the sample size in each Ward. In Masii, Mwala and Kyeni South 53, 107 and 160 farmers were interviewed, respectively. This sample was drawn from a population of 3,267, 6, 711 and 6,572 households in Masii, Mwala and Kyeni South wards, respectively.

Primary data was collected between June - July 2018 from in-person interviews using semi-structured questionnaire. Data on farmer socio-economic characteristics and their WTP for brick cooler, charcoal cooler and solar dryer were collected. Protest answers were determined by first asking the respondents whether they would be willing to pay for each of the PHLRTs and if no, the reasons why were captured. To elicit WTP, the respondents were asked whether they would be willing to pay amounts that ascended or descended from the initial bid. The iterative process ultimately arrived at the respondent's maximum WTP.

Respondents were asked the following questions in the case of a charcoal cooler, brick cooler and solar dryer respectively. “Would you be willing to pay KES 10,000 (USD 100) to construct $1M^3$ of charcoal cooler with a capacity of 163 mango pieces? Would you be willing to pay KES 20,000 (USD 200) to construct $1M^3$ of brick cooler with a capacity of 150 mango pieces? Would you be willing to pay KES 25,000 (USD 250) for $1M^3$ of tunnel solar dryer with a drying capacity of 40 mango pieces? If a farmer accepted the initial bid amount, it was then increased by USD 200 in the case of charcoal cooler until the maximum WTP amount was attained. In the case of brick cooler and solar dryer, if a farmer accepted the initial bid amount, it was then increased by USD 500, until the maximum WTP amount was attained. Where there was a “NO” response to the initial bid, equal decrements of USD 200 (charcoal cooler) and USD 500 (brick cooler or solar dryer) were used until the maximum WTP amount was revealed.

5.3.3 Methods of data analysis

In modeling determinants of WTP, existence of zero values of WTP suggest that the dependent variable shows properties of a corner solution variable (Wooldridge, 2010). A corner solution variable is one which has a significant proportion of the data being zero. This implies that the use of OLS model would be biased. The Tobit model is anchored on a very restrictive assumption (Carroll et al. 2006) that the decision on whether or not to pay and how much are made jointly. Thus, similar factors affect the two decisions. However, the decision to pay precedes that on the level of payment and hence the explaining variables at the two levels may differ (Liebe et al., 2010). An alternative to the Tobit model is the Probit - Tobit model whose estimation involves determining the probability of participation (ρ) and non-participation (1-ρ) (Deaton and Irish, 1984). This model seems appropriate but the unique value of the ρ parameter for all respondents limits it.

The Heckman (1979) correction method allows for better estimators by correcting the self-selection bias caused by the corner solution. The Heckman and the double-hurdle are both two-stage models. However, Heckman assumes the absence of zero observations after passing the first hurdle. In this case, the double-hurdle model is more appropriate (Lera-López et al., 2014). The model accounts for the possibility that zeros are due to non-participation in the market for reasons that may not be economic. The double-hurdle model assumes that determinants of participation and expenditure are allowed to differ and emanate from two different choices. However, biased estimators may be as a result of lack of normality in the data (Box and Cox, 1964). This may be addressed using a Box-Cox variant of the double-hurdle model in which the dependent variable is transformed.

The independent variables were selected based on literature. *Experience* measured as a continuous variable was the duration in years that the respondent had been engaged in mango production; *Marital status* was a dummy variable which was equal to 1 if the respondent was married, 0 otherwise; *Price of technology* was the initial bid amount and was captured as a dummy variable equal to 1 if the respondent said yes to the initial bid amount, 0 otherwise; *Credit access* was a dummy variable which was equal to 1 if the household accessed credit within the last one year, 0 otherwise; *Agricultural Group membership* (AGM) was a dummy variable which was equal to 1 if the respondent belonged to an agricultural related group, 0 otherwise; *Market access* was a dummy variable which was equal to 1 if the respondent had access to markets for mangoes, 0 otherwise; *Tenure* was a dummy variable which was equal to 1 if the household enjoyed formal land tenure, 0 otherwise; *Mango income* was the log of the income reported by respondents. *Extension access* was a dummy variable which was equal to 1 if the household accessed agricultural extension services within the last one year, 0 otherwise; *Awareness* was a dummy variable which was equal to 1 if the household was aware of PHLRTs, 0 otherwise. To estimate the double hurdle model, STATA version 14 was used.

5.3.4 Diagnostic Tests

The extent of correlation among the variables included in the model was tested before estimating the model. Inclusion of related variables in an econometric model leads to the problem of multicollinearity. The presence of multicollinearity thus poses a challenge in the isolation of the relationship between each independent variable and the dependent variable. If present in a model, multicollinearity leads to high standard errors of coefficients, high R-squared despite the insignificance of individual estimates and wrong signs of coefficients (Gujarati, 2004). This study used variance inflation factors (VIF) to test for multicollinearity. Variables with a VIF >5 have high multicollinearity (Greene, 2002). The VIF < 5 of the independent variables (Table 5.1) indicates a low degree of multicollinearity which does not affect results and justified the inclusion of the variables in the model.

Table 5.1: Multicollinearity test – variance inflation factors

Variable	Variance inflation factor (VIF)	Tolerance (1/VIF)
Experience	1.16	0.862150
Mango income (ln)	1.14	0.875099
Agricultural Group Membership (AGM)	1.12	0.894408
Extension Access	1.10	0.912386
Tenure	1.08	0.923393
Credit Access	1.07	0.938320
Awareness	1.07	0.938749
Price of technology	1.05	0.955207
Market Access	1.03	0.966833
Marital Status	1.01	0.986539
Mean VIF	1.08	

5.4 Results and discussion

5.4.1 Data description

Summarized descriptive statistics show that respondents had experience in mango production as indicated by an average of over 9 years in mango production (Table 5.2). It was therefore expected that these respondents would make informed decisions in a bid to reduce postharvest losses. Results revealed that mango production is dominated by elderly married men. It was however surprising that their access to credit was consistently low in both Counties. This can be attributed to the informal land tenure system that poses a challenge in securing credit. Access to agricultural extension services and belonging to agricultural group were also consistently low. Awareness on the PHLRTs was low. However, most respondents had access to markets and high income per season. Majority of the respondents were willing to pay for charcoal cooler that was more affordable than the zero-energy brick cooler and solar dryer.

Table 5.2: Selected summary statistics of respondents

Variables	Embu County n=160		Machakos County n= 160	
	Mean	Std. Deviation	Mean	Std. Deviation
Experience (Years)	10.92	6.90	9.25	5.74
Gender (% Male)	0.84	0.36	0.82	0.39
Marital Status (% Married)	0.78	0.42	0.79	0.41
Credit access (% Yes)	0.08	0.26	0.03	0.16
Agricultural group membership (% Yes)	0.22	0.42	0.16	0.37
Received extension services (% Yes)	0.43	0.50	0.34	0.47
Access to market for mangoes (% Yes)	0.78	0.42	0.81	0.39
Land tenure (% Formal)	0.77	0.42	0.43	0.50
Age of household head (Years)	58.09	14.71	60.51	13.93
Awareness on PHLRTs (% Yes)	0.62	0.49	0.45	0.50
WTP for charcoal cooler (% Yes)	0.71	0.45	0.81	0.40
WTP for brick cooler (% Yes)	0.50	0.50	0.61	0.49
WTP for tunnel solar dryer (% Yes)	0.48	0.50	0.48	0.50
Income from mangoes per season (USD)	548.67	1084.63	402.53	638.28

Source: survey data (2018)

5.4.2 Assessment of mean willingness to pay for postharvest loss reduction technologies

Results show that the mean WTP amount in Embu and Machakos Counties, respectively was on average 35%, 58% and 60% lower than the market price of the charcoal cooler, zero energy brick cooler and tunnel solar dryer (Table 5.3). Producers' WTP has been demonstrated to be significantly lower than market prices (Channa et al., 2019). This is often the case when there is lack of prior awareness of the proposed technologies as was the case in this study. However, the WTP amount for the tunnel solar dryer in Machakos was 17% higher than that in Embu County. This is attributable to the higher temperatures in Machakos County and market access. This finding is supported by Maalouf and Chalak (2019) who found that farmers who easily access wholesale markets express significantly higher WTP amounts for PHLRTs.

Table 5.3: Mean willingness to pay for postharvest loss reduction technologies

Postharvest technologies	**Mean WTP (USD)**		**Market price (USD)**
	Embu	**Machakos**	
Charcoal cooler (1M^3)	67.19	62.80	100
Zero energy brick cooler (1M^3)	93.67	76.11	200
Tunnel solar dryer (1M^3)	92.24	108.22	250

Source: Survey Data (2018)

5.4.3 Determinants of farmers' willingness to pay for postharvest loss reduction technologies

Since the independent variables of the probit model are non-linear, the coefficients are not directly interpreted. Marginal effects are therefore reported at the means for individual independent variables (Table 5.4). The probability that farmers would pay for the PHLRTs was positively influenced by the price of the technologies, marital status, belonging in an agricultural group, access to markets, mango income, number of years in mango farming and having access to agricultural extension services. The WTP amount for PHLRTs was positively influenced by the price of the technologies, agricultural group membership, income from mangoes, marital status, access to agricultural extension services and awareness on PHLRTs.

However, land tenure significantly influenced WTP amount negatively. Price significantly influenced the probability of WTP for PHLRTs by 25% - 55% at one percent level of significance. Minimum prices of the PHLRTs which were presented to respondents as the initial bid had a positive significant (at one percent) influence on the WTP amount for all the PHLRTs in the two Counties. An increase in the initial bid amount occasioned an increase in the household mean WTP for the charcoal cooler, brick cooler and the tunnel solar dryer by KES 8,999 (USD 89.99), KES 12,225 (USD 122.25) and KES 54,100 (USD 541), respectively. This was expected as price is one of the key determinants of demand.

Table 5.4: Determinants of farmers' willingness to pay for postharvest technologies

Independent Variables	Embu County						Machakos County					
	First Hurdle			**Second Hurdle**			**First Hurdle**			**Second Hurdle**		
	Prob. WTP			**WTP Amount**			**Prob. WTP**			**WTP Amount**		
	dy/dx			**Coefficient**			**dy/dx**			**Coefficient**		
	CC	**BC**	**SD**	**CC**	**BC**	**SD**	**CC**	**BC**	**SD**	**CC**	**BC**	**SD**
Experience	0.01	0.13**		-246.83	12.48	-188.58				-72.82	-75.82	-152.21
Marital Status				-518.88	-762.46	497.81			0.19**	1202.14*	1275.88	8077.59
Price	0.25***	0.55***		12875.03***	14549.97***	21442.99***				8998.61***	12225.24***	54100.39***
Credit Access		0.22		-6660.86	-1791.602	2596.54				1488.07	-1481.08	5715.59
AGM	0.13	0.15	0.21**	5025.11	735.90	5234.69*				1100.30*	-57.013	-6619.07
Market access	0.166**			-816.49	-532.67		0.179***	0.176*		-910.383	-1174.884	-11782.42
Tenure			-0.07	965.32	897.81	-2064.29	-0.097*			-1709.81***	257.81	11243.37
Aware				1529.26	-304.80	-3833.74	0.09			-270.98	1893.03**	2037.90
Extension Access		0.25***	0.23***	-309.08	1827.75**	521.43	0.14**				48.48	533.49
Mango income (ln)	0.023**	0.02**	0.07***	.6253	-59.42	152.13	0.029***	0.0155	0.02*	191.12*	-2.57	3640.05*
Constant				2461.61	2954.04	7217.95				2475.28	3662.39	15838.19
Number of observations				160	160	160				160	160	160
Log likelihood				-1146.55	-830.14	-864.82				-1215.36	-962.39	-942.54
Wald chi2				27.36	29.58	20.34				27.70	5.27	6.88
Prob > chi2				0.0000	0.0000	0.0004				0.0000	0.0717	0.0320

*****, ****** and ******* denote statistical significance at 10%, 5% and 1% respectively

CC: Charcoal Cooler, BC: Brick Cooler, SD: Solar Dryer

AGM: Agricultural group membership

Marital status positively influenced WTP for the PHLRTs. Being married increased the probability of WTP for PHLRTs by 19% at five percent level of significance. This is attributable to the need for married people to increase the productivity of their farms to feed their families (Elemasho et al., 2017a). This finding is also recorded by Vilane et al. (2012) who reported that adoption of a PHLRT was mainly by married people. Being a member of an agricultural group increased the probability of WTP for PHLRTs by 21% at five percent level of significance. Agricultural group membership positively influenced WTP amount for PHLRTs. This confirmed to the apriori expectation that organized farmers are empowered and therefore possess higher bargaining power for cost-effective technologies.

Having access to markets increased the likelihood of WTP for PHLRTs by 17% and 18% (at one percent level of significance) in Embu and Machakos Counties, respectively. This can be explained by farmers' need to minimize losses and extend shelf life of their produce in order to maintain steady supply of produce to the markets throughout the year. As expected, income from mango production positively influenced the WTP amount. This is because farmers with higher incomes have higher purchasing power. Experience of mango farming increased the chances of WTP for brick cooler by 13% in Embu County. This result agrees with findings of Maalouf and Chalak (2019) who found that experience significantly influences WTP amount for PHLRTs. A plausible explanation is that experienced farmers appreciate the high magnitude of PHLs and are therefore willing to invest in proven PHLRTs for the reduction of postharvest losses.

Access to agricultural extension services increased the likelihood of WTP for PHLRTs by 14% - 25% and increased the household mean WTP amount for brick coolers by KES 1,827 (USD 18.27) in Embu County. This was expected as agricultural extension services introduce farmers to novel technologies including technologies for postharvest management.

Awareness on PHLRTs increased the household mean WTP amount for brick coolers by KES 1,893 (USD 18.93) in Machakos County. A possible explanation is that awareness on farm technologies influences perceptions and thereby demand for these technologies. This finding is in line with that of Elemasho et al. (2017b) who found that increased awareness and perception of postharvest technology increased its probability of adoption. Land tenure decreased the probability of WTP for charcoal coolers by 10% and the WTP amount for charcoal cooler by KES 1710 (USD 17.10) in Machakos County. This is attributable to the uncertainty resulting from tenure insecurity in the County. This result is at variance with Bokusheva (2012) who found that acquisition of a postharvest storage technology is influenced by ownership of land.

CHAPTER 6: ASSESSMENT OF CONSUMER AWARENESS AND WILLINGNESS TO PAY FOR NATURALLY PRESERVED SOLAR-DRIED MANGOES3

6.1 Abstract

In Kenya, processing of mangoes is underdeveloped and despite the country being the leading mango producer in Africa, most of the produce fails to reach the consumer due to postharvest losses (PHLs). Contemporary consumers prefer purchasing processed products that can be found in many outlets throughout the year, have multiple uses, can stay longer and are not messy. Drying reduces the moisture content in mangoes, ceasing or limiting metabolic activities making it impossible for micro-organisms to survive. Mangoes are seasonal and drying preserves them for months without significant loss of nutrients. The dried product is relatively new in Kenya and little is known on consumer awareness of it. Natural preservatives are healthier and it is necessary to understand whether preserving mangoes using them would fetch a premium price. Further, factors that would influence WTP for the product are not known. Thus, this study sought to address this knowledge gap. Accidental sampling procedure was used to identify 414 consumers of fresh and value-added fruits in the supermarkets in Nairobi. Consumer awareness and WTP were analyzed descriptively. The WTP was explained using the tobit model. Only 16% of consumers were aware of solar dried mangoes. Consequently, only few consumers were willing to pay for NPSDM. Some of the determinants of consumer WTP for NPSDM were access to food information through the mass media, purchase of mango products from retail stores and having tasted solar dried mangoes.

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[3] Mujuka, E., J. Mburu, A. Ogutu, J. Ambuko, G. Magambo. 2021. Consumer awareness and willingness to pay for naturally preserved solar-dried mangoes: Evidence from Nairobi, Kenya. *Journal of Agriculture and Food Research,* 15 (100188). https://www.sciencedirect.com/science/article/pii/S2666154321000909

Promoting the product through the media and in retail stores is recommended to improve awareness and demand. These results are useful for product and niche market development for NPSDM.

Key words: Consumer awareness; postharvest losses; solar dried; tobit model; WTP

6.2 Introduction

Postharvest losses in fruits are estimated at 40% - 50% in Kenya and are higher than the global estimate of postharvest losses (Gustavsson et al., 2011). The high moisture content in fruits drives their perishability and enhances postharvest losses (Ngasoh et al., 2018). Mangoes are also prone to many physiological and pathological challenges which include anthracnose, jelly seed and sunburns, all of which lower mango prices and their competitiveness (Brecht et al., 2020).

Ripe mangoes can either be value added into dried or wet products as one of the measures to reduce postharvest losses. Drying reduces the moisture content in mangoes, thereby, limiting metabolic activities (Mujumdar et al., 2007). Thus, drying extends their shelf-life making them available throughout the year. Drying of mangoes and other fruits concentrates health functional substances such as antioxidants (Rababah et al. 2005) and can also be geared at improving product quality, improving portability and in further processing (Balasuadhkar et al., 2016).

The FAO/WHO recommend a daily intake of 400g of fruit and vegetables (Genkinger, 2004; WHO, 2003). While high rates of malnutrition are prevalent in less developed countries due to lack of access to healthy food (Swinburn et al. 2011), developed countries contend with high cases of health disorders linked to low consumption of nutritious foods such as fruits despite their availability (Anesbury et al., 2018). Inadequate intake of horticultural products is a key issue in the global challenge of poor nutrition (FAO, 2014c). One of the barriers to achievement of the required fruit and vegetable consumption is the lack of time required for their preparation, given that convenience has emerged to be one of the top global trends (Euromonitor International, 2007). Contemporary consumers prefer purchasing processed products to save on cooking time, storage space and the fact that processed products are more presentable (Rosegrant et al., 2001). Consequently, consumers prefer fruit products that are suitable for multiple uses, can stay longer and are not messy (Jaeger et al., 2006). There is need for the food industry to adjust to this emerging trend (Jabs and Devine, 2006).

Demand for mangoes and other assorted fruits and vegetables year-round is rising globally due to an increase in population, societal affluence, lifestyle change, and awareness of health and nutritional benefits (Opara et al., 2007; Suntharalingam and Terano, 2017). According to Altendorf (2019), the United States of America and the European Union are the world's biggest importers of mangoes and mango products. This is the main tropical fruit whose imports have been on the rise in Europe since 2012 (CBI, 2016). Despite knowing the benefits of mangoes and other fresh fruits, Europeans find their preparation and storage inconvenient (CBI, 2017; CBI, 2020). Higher disposable income has increased expenditure on more convenient foods in terms of the time and labour spent in preparing them.

Mangoes are seasonal and drying preserves them for even years without significant nutrient loss (Ortiz et al., 2015). There is a dearth of knowledge on consumer awareness of dried fruits in Kenya. According to Sijtsema et al. (2011) in Europe, dried fruit is perceived as healthier than regular snacks. Consequently, the import of dried mango has maintained an upward trend and this will continue following the rising demand for fresh and processed horticultural produce (Sabbe et al., 2008). This rising demand is driven by increased health consciousness and awareness of dried mango (Alterndorf, 2019). Europe imports mangoes mostly from developing countries (CBI, 2016). Nonetheless, most Europeans consume lower amount of fruit than is recommended (WHO, 2013). There is need to develop dried fruit as a healthy snack for the export market in Europe and for the local market.

The processing of mangoes in Kenya is underdeveloped. The domestic market for fresh fruit currently constitutes about 98% of the mango produced in the country, with only about 2% exported at approximately USD 1.5 million per year (HCD, 2017). Although the country is the highest mango producer in East Africa (FAOSTAT, 2021), most of the produce fails to reach customers due to perishability (Mungai et al., 2000).

The PHLs impact negatively on household income, food and nutrition security. The prevalence of undernourishment over the period 2014-2016 was approximately 20% of the total population in Kenya (FAO, 2017). Processing of mangoes has the potential to reduce the malnourished population in Kenya and beyond through the saved fruit because mangoes are rich in vitamins and essential minerals. Processing of mangoes preserves the fruit, improves produce value and thereby farm incomes. The focus within the post-harvest activities in developing countries is slowly shifting from reduction of PHLs to a more holistic approach aimed at supply chain development (Mrema and Rolle, 2002). Efficiency in marketing ensures more gains for producers, reduces the concentration of middlemen, marketing charges and marketing mal-practices (Panda and Sreekumar, 2012).

The severity of PHLs is exacerbated by the lack of market opportunities among smallholder farmers (Hodges et al., 2011). This is partly due to a weak agro-processing sector, which is dominated by small, private food processing businesses that struggle to meet market demand and/or compete with imported foods. Local processors suffer from low processing capacity and frequent variable product quality. These constraints are mainly due to limited access to expertise, technologies, and finances, combined with poor local infrastructure and unfriendly business and policy environments. A strong support system for small scale processors in developing competitive value-added products and derivatives is urgent in expanding markets and reducing postharvest losses. It requires access to appropriate mechanized processing technologies to produce consistently high-quality products for target markets including domestic, regional, or export markets. It is against this background that the Rockefeller Foundation has partnered with the UoN to provide solar tunnel dryers to small scale processors in Kenya. A solar tunnel dryer has three main components which are; a drying chamber for drying food, an airflow system and a solar panel which traps the sun energy and runs a fan that then pushes hot air over the drying produce.

Past studies on dried fruits revealed that they are eaten rather occasionally, with the frequency of consumption increasing with awareness (Jesionkowska et al., 2008). Dried fruit is perceived to lower the chances of cancer and heart diseases among Dutch, Polish and French consumers (Jesionkowska et al., 2009). However, consumers in Ghana, are concerned about the use, function and sensory appeal of dried produce due to lack of information on the processing of dried products (Owureku et al., 2017). The most desired attributes of dried produce among consumers are taste and flavour (Owureku et al., 2017). The decision to purchase solar dried products has been found to be influenced by age, gender, awareness, education, occupation and taste (Ali and Ali, 2020; Kessy et al., 2018; Okello et al., 2015). However, it is not clear whether consumers in Kenya are aware of dried mango products and their WTP for a healthier dried fruit. Furthermore, the key factors influencing this WTP are not known. This information is necessary for product development and strategic marketing. Thus, this study sought to estimate demand for (NPSDM). Specifically, this study sought to establish whether consumers knew of solar dried mangoes, to estimate their WTP amount for NPSDM and the factors influencing the WTP in Nairobi, Kenya.

About a third of the Kenyan population live in urban regions and a third of these reside in Nairobi, County (KNBS, 2019a). The County has a balanced sex ratio with an average household size of three compared to the national average household size of four (KNBS, 2019a). Rising incomes in urban centers is associated with increased expenditure on healthy food choices, particularly horticultural produce. Mango accounts for about 14 percent of the household expenditure on fruits in Nairobi (Bundi et al., 2013). This is due to its higher price per kg, which makes consumers go for its substitutes (banana and avocado) which are relatively cheaper and whose supply are smoother in the market. This study is in line with the United Nation's Sustainable Development Goal (SDG 12.3) which seeks to halve postharvest losses by the year 2030 and the African Union Agenda 2063 which aims at halving PHLs by 2023 from their current levels. It will also support implementation of Kenya's Big Four Agenda which aims at combating food insecurity among other objectives.

6.2.1 Theoretical framework

Consumer WTP is anchored on the theory of consumer utility maximization (Lancaster, 1966). Accordingly, it is assumed that a good possesses several attributes that a buyer relies on to make a choice. Consumer demand is measured by WTP for it. The utility consumers derive from consuming a given good provides the basis for estimating WTP in terms of welfare change. Consumer utility is a function of both market (x) and non-market (y) goods. An individual's utility function can be expressed as $u(x, y)$. The corresponding indirect utility function depends on prices of market goods, p; income of an individual, i; individual characteristics, q; and stochastic component, e. Indirect utility function can be expressed as: $v(p, y, i, q, e)$. A consumer maximizes utility subject to income i. The indirect utility function can be expressed as: $v\ (p, y, i, q, e) = \max \{u(x, p) \setminus p, x \leq i\}$. The minimum expenditure function $m\ (p, y, u)$ is dual to the indirect utility function and is presented as: $m\ (p, y, u) = \min$ (p.x\ u(x,y)$\leq u$).

The derivative of the expenditure function yields the Hicksian or utility-constant (compensated) demand function. The subscript indicates the partial derivative. The negative of the ratio of derivatives of the indirect utility function yields the Marshallian or ordinary demand curve as: u_i $(p, y ,u) = mp_i$ (p, y, u).

A consumer decides to consume a product due to the utility derived from the attributes of the product (natural preservatives, in this case) rather than the good as a whole. This theory further posits that consumers weigh additional gains of value-added products against the change in unit price. The maximum amount of income a consumer would therefore be willing to pay for NPSDM (utility maximization) is defined by the indirect utility function: $v\ (p, y^*, q, i - WTP) = v\ (p, y, i)$ where v denotes the indirect utility function, i the level of a consumer's income, p a vector of prices faced by the consumer and y^* and y are the quality attributes with $y^* > y$, and increases in y^* (natural preservatives in this case) is advantageous since $\frac{\partial v}{\partial y} > 0$ implying that higher consumption of naturally preserved mangoes leads to higher utility.

6.2.2 Conceptual framework

Past studies on WTP provide sufficient evidence that product awareness and socio-demographic factors interact with product attributes to determine WTP for a product. Kessy et al. (2018) analyzed factors affecting WTP for solar-dried traditional African vegetables in Tanzania. The authors showed that gender and awareness influenced WTP. Product awareness is the ability of consumers to know a product (Homburg et al., 2010). The level of consumers' product knowledge influences their use of the same, to form product quality judgments and ultimately, the purchasing decision (Ngigi et al., 2011).

Okello et al. (2015) showed that WTP for sundried and frozen African indigenous vegetables was affected by age, gender, education, product awareness and product attributes. Older and educated consumers were found willing to pay for healthier products. Product attributes are important to consumers in making purchasing decisions. Consumers base their perceptions of dried product attributes on use, functionality and sensory appeal (Owureku et al. 2017). With respect to use, consumers prefer dried fruits as a convenient source of nutrients which is not messy. In terms of functionality, dried fruits are perceived as carriers of functional properties that contribute to the increased consumption of healthy products such as breakfast cereals, muesli bars, cakes, cookies and fruit teas (Jesionkowska et al., 2009). Consumers have also been found to be interested in quality attributes that appeal to their senses. Such quality attributes include taste, flavour, colour, texture and cleanliness. Consumers further use product attributes to rank dried products in order of preference. For instance, taste has been found to be the most preferred quality attribute with a sensory appeal. Enhanced taste is key in the commercialization of dried mangoes. Figure 6.1 illustrates the conceptual framework and the hypotheses that were tested in this study.

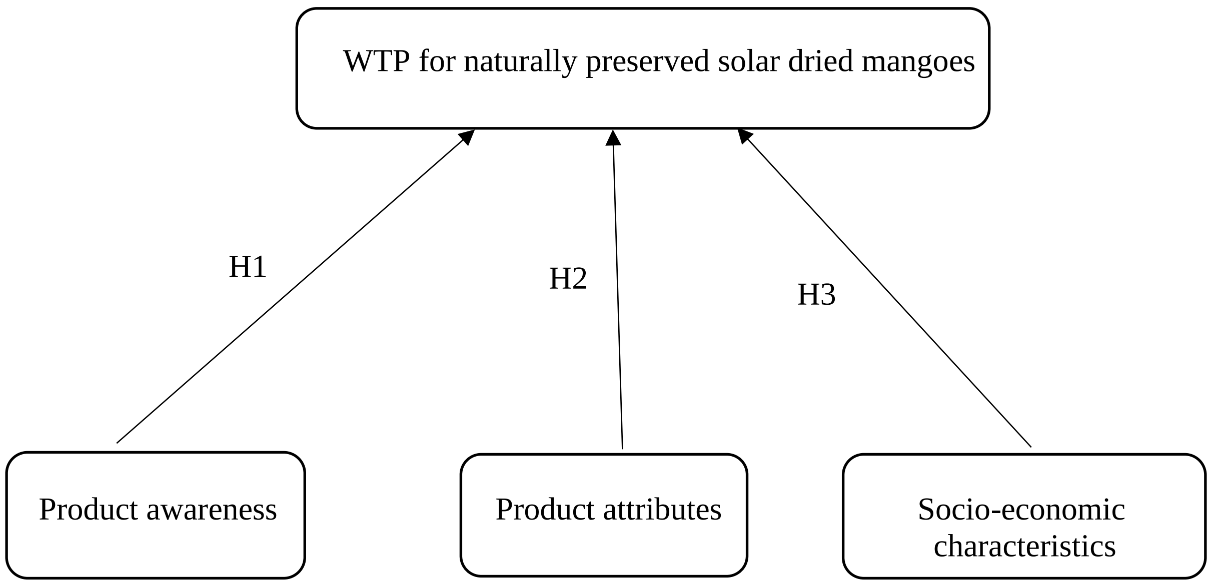

Figure 6.1: Conceptual framework and hypotheses that were tested

The hypotheses tested by this study were that: product awareness has a significant influence on the WTP for NPSDM; product attributes have a significant influence on the WTP for naturally preserved solar dried mangoes and that socio-demographic characteristics have a significant influence on the WTP for NPSDM.

6.3 Methodology

6.3.1 Sampling technique and data collection

Primary data was collected from in-person interviews. The respondents were consumers of fruits and related products. A scoping survey was conducted between 10th and 16th July, 2019 in Nairobi County to identify the main retail outlets specializing in wet and dried mango products. From the scoping survey, we were able to identify when customer flow was highest as well as the relative sizes of the outlets. Most outlets were busy in the evenings leading up to the weekend and during the weekends. Consequently, the study was conducted between 8am and 8pm from Thursday, 30th January to Saturday, 1st February, 2020.

Respondents were sampled from the main supermarkets in Nairobi, namely, Zucchini, Carrefour, Chandarana and Tuskys supermarkets. The survey was conducted in the two busiest branches (in terms of selling fruits and processed fruit products) of each of the four retail outlets. Supermarket chains in Nairobi have different store formats to reach different customer segments (Neven et al., 2006). There are small stores as well as hypermarkets in the city. The study purposively selected the four hypermarkets since, unlike the small stores, they cannot miss to sell fruits and processed fruit products. Hypermarkets also have ample parking space and are strategically located along the main roads or in large shopping malls in the outskirts of the city, and therefore they attract high and middle-income consumers. Smaller stores are usually located in the city center and in some residential areas ('estates'), have lesser parking space and mostly target middle and lower-income consumers. As a marketing strategy, hypermarkets in the city's outskirts stock unique products (such as naturally preserved fruit products) which make them attract high-end customers.

A semi-structured questionnaire that was uploaded in Survey CTO (which is a mobile data collection platform that ensures collection of quality data, that is reliable and secure) was used in collecting data. Enumerators were trained on data collection using the tool. Before conducting the interviews, the data collection tool was pre-tested with the target group. Accidental sampling technique was employed in this study because the sampling frame was an unknown population since in a spot market scenario like in our case, it is almost impossible to get a list of all the visitors to the targeted market outlets and particularly those interested in either fruit and/or processed fruit products. In some outlets there are very few repeat customers and some take long before going back to the same supermarket. Thus, sample size determination before commencing the study was not possible considering the sampling approach used.

The enumerators arrived at the stores as soon as they were opened and only interviewed consumers who either picked fresh fruits and/or processed fruit products. Only one enumerator was allowed per store and the products were located on adjacent shelves. The enumerator on arrival interviewed the first consumer who picked either fresh fruits or dried fruit products. After conducting the interview, the enumerator would then wait near the shelves to spot the next person to pick either fruit or processed fruit products. Then he or she would conduct the next interview. This cycle was repeated throughout the day until the supermarket closed in the evening. In total 414 respondents were interviewed.

Three types of data concerning consumers' purchasing behavior were collected. First, respondents were asked about their awareness of dried mangoes. Secondly, the survey elicited data on consumption of dried mangoes and thirdly, consumers stated their WTP amounts for NPSDM. To reduce the probability of starting-point bias, prices recorded during the scoping survey were used. Then interviewees were asked to respond to the following question: "how much more would you be willing to pay for a 200gm packet of dried mangoes, but which has been preserved using natural preservatives?" Finally, the enumerators gathered social, demographic, and economic information on the households.

6.3.2 Data analysis

Consumer awareness and WTP amount for NPSDM were analyzed descriptively using STATA version 16. The WTP amount is indicative of demand for value added dried mangoes. A two-stage model was not used in this study since the decision to purchase and how much to pay for NPSDM are not made separately. While awareness has been found to influence WTP, some purchases are made without prior product knowledge or on impulse. Further, given the high number of zero values of WTP, the Tobit model was used to analyze factors influencing WTP for NPSDM, following Green (2002). A dependent variable with a significant number of zero values of WTP calls for a censored regression model (also known as a Tobit model) because standard Ordinary Least Square (OLS) technique results in biased and inconsistent parameter estimates. The bias arises from the omission of the zeros and therefore no guarantee that the expected value of the error term will be necessarily zero.

Following Greene (2003) the Tobit model can be specified as;

$$MWTP_i^* = B' X_i + \mu_i \tag{6.1}$$

$$MWTP_i = \begin{cases} MWTP_i^* \; if \; MWTP_i^* > 0 \\ 0 \; if \; MWTP_i^* \leq 0 \end{cases} \tag{6.2}$$

Where, $MWTP_i^*$ is the unobserved WTP for NPSDM; $MWTP_i$ is consumer's maximum WTP for NPSDM; B is a vector of some unknown coefficients; X_i are independent variables hypothesized to influence consumers' maximum WTP; $\mu_i$is the error term which is assumed to be normally distributed with a mean of zero and constant variance.

$$MWTP^* = \mathcal{B}_0 + \beta_1 AGE + \beta_2 GEN + \beta_3 MS + \beta_4 EDUC + \beta_5 OCCUP + \beta_6 AWARE + \beta_7 MM + \beta_8 RSTORE + \beta_9 TASTE + \mathcal{E}_i \tag{6.3}$$

The dependent variable in Equation 3 was empirically measured by the stated maximum WTP for NPSDM. The independent variables were selected based on literature. *AGE* measured as a continuous variable is the age of the respondent in years; *GEN* is a dummy variable which was equal to 1 if the respondent was female, 0 otherwise; *MS* is a dummy variable which was equal to 1 if the respondent was single, 0 otherwise; *EDUC* measured as a continuous variable was the number of years of formal education of the respondent; *OCCUP* is a dummy variable which was equal to 1 if the respondent was in formal employment, 0 otherwise; *AWARE* is a dummy variable which was equal to 1 if the respondent was aware of dried mangoes, 0 otherwise; MM is a dummy variable which was equal to 1 if the respondent sought for food information from the mass media, 0 otherwise; RSTORE is a dummy variable which was equal to 1 if the respondent made their purchases from retail stores, 0 otherwise; TASTE is a dummy variable which was equal to 1 if the respondent had tasted naturally preserved mango juice, 0 otherwise.

6.3.3 Diagnostic Tests

This study tested for the existence of multicollinearity and heteroscedasticity before the model was estimated. Multicollinearity tests the extent of correlation among variables while heteroscedasticity explains the relationship between the error terms across variables. Multicollinearity arises when related variables are included in an econometric model and limits the estimation of separate influence of independent variables on the dependent variable. Presence of multicollinearity result in high standard errors of coefficients, high values of R-squared despite the individual estimates being insignificant and wrong signs of coefficients (Gujarati, 2004). This study employed variance inflation factors (VIF) to test for multicollinearity. Variables with a VIF >5 have high multicollinearity (Greene, 2002). The VIF < 5 of the independent variables (Table 6.1) indicate absence of multicollinearity and justified their inclusion in the model. Heteroscedasticity refers to error terms whose variances are not constant across observations (Greene, 2008).

Table 6.1: Multicollinearity test – variance inflation factor

Variable	VIF	1/VIF
Marital status	1.66	0.600888
Age	1.64	0.610449
Education	1.2	0.833965
Occupation	1.1	0.906766
Taste	1.1	0.912556
Aware	1.09	0.918662
Retail store	1.02	0.984082
Mass media	1.01	0.986387
Gender	1.01	0.986519
Mean VIF	1.2	

Heteroscedasticity was tested using a Breusch-Pagan / Cook-Weisberg test. The null hypothesis was that residuals were homoscedastic. Since the Chi-square was significant (chi2(1) = 12.57; Prob > chi2 = 0.0004), we rejected the null hypothesis of existence of homoscedasticity in favour of the alternative hypothesis of existence of heteroscedasticity. Following Wooldridge (2000) robust standard errors were used. Model specification was examined using the Ramsey RESET test which tests for omitted variables. The estimated p-value was 0.10 indicating that no significant variables were excluded from the model.

6.4 Results and discussion

6.4.1 Characteristics of the respondents

Majority of the respondents were middle aged consumers who had experience in shopping and accessed food information through the media (Table 6.2). However, respondents who were willing to buy dried mangoes were older than those who were not, and most of them also accessed food information through the media. Although most of the respondents were literate (having spent an average of 17 years pursuing formal education) consumers who were willing to buy dried mangoes were more educated than those who were not willing to buy dried mangoes. The respondents were mainly urban dwellers and all those who were willing to buy dried mangoes resided in the urban areas. A large proportion of the consumers were female. This agrees with findings of studies involving urban consumers in Kenya (Okello et al. 2015) and implies that women are responsible for household fruit purchasing decisions. This figure is relatively higher than those reported in other studies in Kenya and is attributable to the targeting of high-end retail outlets which were expected to be stocking a wide range of value-added fruit products. Most of the respondents were married, with an equal proportion expressing willingness to buy dried mangoes or otherwise. Half of the respondents were in formal employment and almost all of them were willing to buy dried mangoes.

Table 6.2: Socioeconomic characteristics of the respondents

Explanatory variable (n=414)	**Mean**	**Willingness to Buy Dried Mango**	
	Pooled	**Yes (n=122)**	**No (n=292)**
Age (years)	39.59	42.41	38.41
Education (years)	17.21	19.24	16.37
Residential area (% Urban)	0.98	1	0.93
Gender (% Female)	0.58	0.73	0.51
Marital status (% Married)	0.70	0.70	0.71
Occupation (% formal)	0.50	0.48	0.5
Access to Mass Media (% Yes)	0.66	0.79	0.58
Awareness of dried mangoes (% Yes)	0.16	0.13	0.17
Consumption of Dried-mangoes (% Yes)	0.06	0.05	0.07
Frequency of consumption (1= Weekly 0=otherwise)	0.02	0.02	0.02

Source: Survey data (2020).

6.4.2 Awareness and consumption of solar dried mangoes

Only about a sixth of the respondents were aware of dried mangoes and it was surprising to note that a slightly higher proportion of those who were aware of them were not willing to buy them (Table 6.2). Further, out of only 6% of the consumers who had consumed dried mangoes, a slightly higher number of these were not willing to buy them. Generally, dried mangoes are consumed on occasional basis. Solar dried fruits and vegetables are new products in the region. This finding concurs with findings of Owureku et al. (2017) who found that only 9% of the consumers were aware of dried tomatoes and a meagre 3% had consumed them. However, there is more donor interest in the vegetable sub sector, in both Kenya and Tanzania. This has led to increased investment in value addition of vegetables and awareness of solar dried vegetables. Consequently, consumer awareness of solar dried vegetables is higher and estimated at 79% and 36% in Kenya and Tanzania, respectively, with occasional consumption reported in both countries (Kessy et al., 2018; Okello et al., 2015).

6.4.3 Mean willingness to pay for naturally preserved solar dried mangoes

About a third of the consumers were willing to pay for NPSDM. Results indicate that consumers in Nairobi are willing to pay a premium (29 %) for NPSDM (Table 6.3). This implies that NPSDM are acceptable. This result is consistent with the work of Otieno and Nyikal (2017) who found that consumers in Kenya do not prefer colorants, flavors, and preservatives in their fruit juices. These consumers were willing to pay premiums of up to 200% for artisanal juices that lack additives.

Table 6.3: Comparison between actual average price and mean willingness to pay for naturally preserved solar dried mangoes

Variable	Mean (USD)	SD
Price of dried mangoes (200gms)	1.39	0.77
WTP for naturally preserved dried mangoes	1.80	0.76

Source: Computed from survey data, 2020

6.4.4 Factors influencing consumer willingness to pay for naturally preserved solar dried mangoes

The dependent variable of the estimated Tobit model (Table 6.4) was the maximum WTP amount (in Kenya shillings). Age, gender, number of years of formal education, marital status, mass media, having tasted naturally preserved mangoes and purchasing from retail stores were the factors that positively influenced consumer WTP amount for NPSDM (Table 11). Four out of the five socio-demographic factors that were hypothesized to influence WTP for NPSDM were significant. Therefore, we fail to reject the hypothesis that socio-demographic characteristics have a significant influence on the WTP for NPSDM.

Older consumers were willing to pay for dried mangoes which are healthier. This finding is important and shows that older consumers are more concerned about food safety in a bid to avert diseases associated with chemical preservatives. This result corroborates that of Okello et al. (2015) who found that older consumers were willing to pay for solar dried cowpea leaves. As expected, female consumers were willing to pay a premium for a more natural product, given that they are more health conscious (Wardle et al., 2004). Being female increased WTP for NPSDM by KES. 2.38.

Table 6.4: Determinants of consumer willingness to pay for naturally preserved dried mangoes

Variable	Coefficient	SE
AGE	0.06	0.025**
GEN	2.38	0.572***
MS	1.69	0.772**
EDUC	0.36	0.074***
OCCUP	0.20	0.554
AWARE	0.80	0.782
MM	1.21	0.663*
RSTORE	3.05	1.279**
TASTE	1.47	0.568**
Number of observations	414	
Log Pseudo likelihood	-473.81	
LR chi2 (9)	81.21***	
Pseudo R^2	0.08	

Note: Statistical significance levels: ***1%; **5%; *10%.

More years of schooling increased WTP for NPSDM as expected. This implies that educated consumers are more knowledgeable on chemical preservatives and more receptive to quality and health aspects. This finding agrees with Kayisoglu & Coskun (2016) who found a significant relationship between respondent’s education level and knowledge on food additives. Further, Ali and Ali (2020) also found that the education level positively influenced consumer WTP for health and wellness products. Married consumers were willing to pay for a healthier snack. This was expected, due to their higher capacity to pull resources, including sharing new product information.

Consumers who source for food information from the media were willing to pay for a better quality of dried mangoes. This result is not surprising because the media has been active in promoting value addition and highlighting harmful effects of chemicals on human beings. Access to safe food at the retail level has been affected by a number of reports of chemicals (Kunyanga et al. 2018) which are risky to consumers particularly vulnerable populations (Chiu et al., 2018). About 70% of all cases of diarrhea are attributed to consumption of contaminated food or water (FAO/WHO, 2005). Huge economic and social losses are linked to the presence of chemicals in food (Alegbeleye et al., 2018).

Retail stores have endeavored to complement efforts of the food processing industry and in a convenient way for consumers. Consumers who purchase their mangoes from retail stores were willing to pay for NPSDM. This implies that consumers are responding positively to the increased investment in value addition of fruits and vegetables by retail stores to capture more of consumers' food dollar. This result follows the assertion of Ali and Ali (2020) that consumers who value shopping experience are willing to pay more for healthy food products.

Consumers who had tasted naturally preserved mango were willing to pay for NPSDM. This agrees with past studies (Yu et al. 2018) that found strong evidence on the significant role of preference of product quality attributes on healthy food consumption. Further, this result is the basis for failing to reject the hypothesis that product attributes have a significant influence on the WTP for NPSDM. The result that awareness of solar dried mangoes was not significant contradicts literature (Kessy et al. 2018; Okello et al. 2015) that maintain that product knowledge positively influences consumer WTP for dried vegetables. A plausible explanation is the higher level of awareness of dried vegetables among consumers. Consequently, we reject the hypothesis that product awareness has a significant influence on the WTP for NPSDM.

CHAPTER 7: SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

7.1 Summary

In Kenya, approximately 50% of mangoes are lost postharvest. This negates the gains from horticultural research that aim at increasing productivity at a time when 25% of the population is undernourished and severely food insecure. The postharvest losses in horticulture are higher than the global estimate and are driven by high perishability. Lack of access to postharvest technologies for cold storage and value addition has been found to further increase postharvest losses. A number of national, regional and international initiatives are increasing to reduce postharvest losses across all value chains across the world.

The Kenyan government acknowledges the significant PHLs across all value chains due to lack of storage and food preservation technologies. The government therefore seeks to promote storage and processing of agricultural produce through supporting private players involved in postharvest management in the country. Consequently, the UoN sought to create awareness and provide applicable, and proven PHL reduction technologies to smallholder farmers in Kenya. The technologies include tunnel solar dryers for value addition of mangoes and which extends their shelf life by up to one year. Other technologies are ECTs such as charcoal and zero energy brick coolers that are applicable in most rural households without access to electricity. These technologies are not new globally but their adoption in Kenya is limited.

However, before upscaling the proposed PHLRTs, it was important to understand the potential economic impact of investment in PHLRTs and WTP for the PHLRTs and their value-added products among mango producers and consumers in Kenya. Thus, this study specifically sought to: (i) Estimate the potential economic impact of PHLRTs among smallholder mango farmers; (ii) Analyze smallholder farmer's WTP for PHLRTs and its conditioning factors in Kenya; and (iii) Assess consumer awareness and WTP for NPSDM in Nairobi County.

To achieve the first and second objectives, key informant interviews and household survey were conducted. Multistage sampling was employed in the household survey and at the first stage, a sample of 320 households was purposively selected from Embu and Machakos Counties. These Counties had previously implemented a project which focused on reduction of preharvest losses. The third objective was achieved through a consumer survey which targeted 414 consumers from the main retail outlets in Nairobi County.

The expected gains of investing in the proposed PHLRTs to consumers and producers were estimated using the ESM. A CBA revealed the potential economic impact of investing in PHLRTs. Using a 10% maximum adoption and discount rate, the NPV of investing in PHLRTs was estimated at US $ 1.29 billion, the IRR was 28% while the BCR was 4:1. Sensitivity analyses were undertaken and the adoption rates and discount rates were found to be the key drivers of the viability of the investment. Increasing the adoption rate by 2% the NPV increased by 255% while the IRR and BCR more than doubled. Reducing the interest rate by 2% increased the NPV by 25%. Further, increasing the interest rate by 2% reduced the NPV by 23% and the BCR to 3.9.

About 62% and 45% of farmers in Embu and Machakos Counties were aware of PHLRTs yet slightly more producers in Machakos expressed WTP for the PHLRTs. On average, about 76%, 56% and 48% of the producers in both Counties were willing to pay for the charcoal cooler, the zero-energy brick cooler and the tunnel solar dryer. However, the WTP amounts for the charcoal cooler, the zero-energy brick cooler and the tunnel solar dryer in both Counties were on average lower than the market prices by 35%, 56% and 60% respectively. Further, only about 39% of the farmers in both Counties had access to agricultural extension services.

The CVM method was employed to elicit producers' and consumers' WTP for the PHLRTs and value-added product, respectively. A double hurdle model showed that producers' probability to pay for PHLRTs is positively influenced by their marital status, price, belonging in an agricultural group, access to markets and mango income. Gender negatively and positively influenced the probability to pay in Embu and Machakos, respectively. The maximum WTP amount was found to be positively influenced by price, belonging to an agricultural group, and mango income. However, age, land tenure, experience in mango production, access to credit and access to markets negatively influenced the WTP amount.

Only 16% of the consumers were aware of solar dried mangoes. Consumers who were aware of solar dried mangoes accessed the information through mass media and retail stores. Consumers expressed WTP a premium of 29% for tasty NPSDMs depending on whether they had accessed food information through the mass media, they preferred purchasing mango products from retail stores and whether they had tasted naturally preserved mangoes.

7.2 Conclusions

It was hypothesized that investing in PHLRTs for smallholder mango farmers is not worthwhile. This hypothesis was rejected based on the positive profitability indices such as the NPV. Both producers and consumers are expected to gain from the adoption of the technologies. The technologies are expected to reduce postharvest losses thereby increasing productivity and producer incomes. With increased production, prices are expected to fall, increasing consumer surplus. The economic viability of the technologies can also be increased by employing them across other horticultural value chains. Thus, the expected benefits outweigh the costs. This study concludes that investment in PHLRTs is worthwhile.

The hypothesis that smallholder mango producers are not willing to pay for PHL reduction technologies was also rejected following results that revealed the proportion of mango producers that were willing to invest in each of the technologies. Further, WTP amounts for each of the technologies despite the low awareness show that the technologies are acceptable among mango producers. According to the study, the main driver influencing WTP for the PHLRTs is price. Producers responded positively to lower initial bids in expressing their WTP for PHLRTs.

Finally, the hypothesis that consumers are not willing to pay for NPSDM was rejected based on the stated premiums that consumers were willing to pay for the value-added product. The acceptability of the value-added mango shows that consumers value safe food and that there is potential for the growth of the food industry through emphasis on food safety.

Price of the value-added product was found to be the main driver influencing WTP. Consumers responded positively to lower initial bids in expressing their WTP for the value-added product. Awareness of dried mango is however low among consumers. Socio-economic characteristics that were found to be significant in explaining WTP amounts among consumers are instrumental in advancing niche markets. This study has demonstrated that upscaling of the proposed PHLRTs is necessary for the reduction of postharvest losses of mangoes. Upscaling of these technologies will reduce unemployment due to the high amount of labour required at different stages of value addition such as sorting, grading, cleaning, packaging, peeling, slicing and drying of mangoes.

7.3 Policy implications

There's need for County governments to enhance agricultural extension programmes for dissemination of information on PHLRTs and their value-added products. This will increase awareness and thereby WTP for the technologies among producers. Further, both public and private extension agents need to promote group formation among farmers and link them to markets for increased demand of the PHLRTs. The County government needs to strengthen tenure security to increase investment in PHLRTs among smallholder farmers. The national government should also stabilize interest rates. Targeted subsidies by the County governments are also proposed to spur demand for the PHLRTs among smallholder farmers. Increased adoption of the technologies will lower product prices for consumers.

More awareness campaigns are required through mass media and in retail stores to increase awareness on the solar dried mango. The food processing industry needs to focus on quality attributes such as taste and natural food preservatives to increase demand of solar dried mangoes. A pricing policy by the County government that awards a premium to safe food is highly recommended. Deterrent measures designed by the County government for non compliance with food safety standards are also critical. The County government needs to incentivize investment in retail stores which are the preferred market outlet for dried fruits. Development partners working on cold storage and processing technologies should also be supported.

7.4 Suggestions for further research

This study found that investment in PHLRTs such as charcoal coolers is viable. However, there is need for:

1. Ex post impact evaluation of the proposed PHLRTs to validate results of this study.
2. A comprehensive environmental impact assessment of use of charcoal as an evaporative cooling agent in the charcoal cooler
3. An analysis of the nutritional content of the solar dried mango
4. Evaluation of spillover effects of investment in PHLRTs
5. Ex-post economic analysis of PHLRTs on efficiency of different mango marketing channels.

REFERENCES

Abbade, E. B. (2020). Estimating the nutritional loss and the feeding potential derived from food losses worldwide. *World Development*, 134, 105038.

Abdulai, A., and Huffman, W. E. (2005). The diffusion of new agricultural technologies: the case of crossbred-cow technology in Tanzania. *American Journal of Agricultural Economics*, 87(3), 645-659. https://doi.org/10.1111/j.1467-8276.2005.00753.x

Adams, F., Amankwah, K., Wongnaa, C. A., Honny, E. P., Peters, D. K., Asamoah, B. J., and Coffie, B. B. (2019). Financial analysis of small-scale mango chips processing in Ghana. *Cogent Food and Agriculture,* 5(1), 1679701. https://doi.org/10.1080/23311932.2019.1679701

Affognon, H. (2010). Potential impact of BMZ investments in trypanocide resistance research. Technical report, ILRI (International Livestock Research Institute), Nairobi, Kenya.

Affognon, H., Mutungi, C., Sanginga, P., and Borgemeister, C. (2015). Unpacking Postharvest Losses in Sub-Saharan Africa: A Meta-Analysis. *World Development*, 66, 49-68.

Alegbeleye, O. O., Singleton, I., and Sant'Ana, A. S. (2018). Sources and contamination routes of microbial pathogens to fresh produce during field cultivation: A review. *Food Microbiology*, 73, 177-208. https://doi.org/10.1016/j.fm.2018.01.003

Alemu, G. T., Z., Nigussie, N., Haregeweyn, Z., Berhanie, B. A., Wondimagegnehu, Z., Ayalew, D., Molla, E., Okoyo, N., and Baributsa, D. (2021). Cost-benefit analysis of on-farm grain storage hermetic bags among small-scale maize growers in north western Ethiopia. *Crop Protection*, 143, 105478.

Ali, T., and Ali, J. (2020). Factors affecting the consumers' willingness to pay for health and wellness food products. *Journal of Agriculture and Food Research*, 2, 100076. https://doi.org/10.1016/j.jafr.2020.100076

AGRA. (2020). Economic Assessment of Government Incentives Required for the Promotion of Wide-Scale Utilization and Local Manufacture of Hermetic Storage Technologies. AGRA, Nairobi, Kenya.

Alston, J. M., Norton, G. W., and Pardey, P. G. (1995). Science under scarcity: Principle and practice for agricultural and priority setting. New York, Cornell University Press.

Altendorf, S. (2019). Major tropical fruits market review 2018. Retrieved January 20, 2020, from http://www.fao.org/3/ca5692en/CA5692EN.pdf

Altendorf, S. (2017). Global prospects for major tropical fruits: short-term outlook, challenges and opportunities in a vibrant global marketplace. Food outlook: 60 biannual report on global food markets, FAO Trade and Markets Division, Rome, Italy.

Ambuko, J., Wanjiru, F., Cheminingwa, G. N., Owino, W. O., and Mwachoni, E. (2017). Preservation of Postharvest Quality of Leafy Amaranth (Amaranthus spp.) Vegetables Using Evaporative Cooling. *Journal of Food Quality*, 1-7.

Andrea, C. (2012). Understanding the marketing chain of mango and grapes in the Sao Francisco valley. Sao Francisco: Universidade.

Anesbury, Z., Greenacre, L., Wilson, A. L., and Huang, A. (2018). Patterns of fruit and vegetable buying behaviour in the United States and India. *International Journal of Market Research*, 60 (1), 14–31. https://doi.org/10.1177/1470785317751997

Anna, B., Hosea, M., Lucy, C., Theodosy, M., Abdul, K., George, T., Jaspa, S., Gopinadhan, P., Alan, S., Jayasankar, S., and Maulid, M. (2020). Evaluation of post-harvest losses and shelf life of fresh mango (Mangifera indica L.) in Eastern Zone of Tanzania. *International Journal of Fruit Science*, 20(4), 855–870. doi: 10.1080/15538362.2019.1697411.

Antle, J. M., Murshed-E-Jahan, K., Crissman, C. C., and Valdivia, R. O. (2015). Simulation-based Ex Ante Assessment of Sustainable Agricultural Technologies: An Application to Integrated Aquaculture-Agriculture in Bangladesh. A report submitted to the Standing Panel on Impact Assessment (SPIA), CGIAR Independent Science and Partnership Council (ISPC).

Aragie, E., Balié, J., and MoralesOpazo, C. (2018). Does reducing food losses and wastes in sub-Saharan Africa make economic sense? *Waste Management and Research*, 36, 483–494.

Arrow, K., Solow, R., Portney, P. R., Leamer, E. E., Radner,R., and Schuman, H. (1993). Report of the NOAA Panel on Contingent Valuation. *Federal Register*, 58 (10), 4601–4614.

Ashok, K. R., Giuliani, A., Thilagavathi, M., Raj, S.V., Ramamoorthy, R., Devi, M., and Sanjeevikumar, A. (2017). Trait valuation in genetically modified crops: An *ex-ante* analysis of GM Cassava against cassava mosaic disease. *Agricultural Economics Research Review, 30* (2), 223-234. https://doi.org/10.5958/0974-0279.2017.00044.1

Asmare, E., Bekele, K., and Fentaw, S. (2022). Households' willingness to pay for the rehabilitation of wetlands: evidence from Gudera Wetland, Northwest Ethiopia, *Heliyon,* 8.

Atreya, K. (2007). Farmers' willingness to pay for community integrated pest management training in Nepal. *Agriculture and Human Values*, 24, 399–409. https://doi.org/10.1007/s10460-007-9063-3

Aulakh, J., and Regmi A. (2013). Post-Harvest Food Losses Estimation-Development of Consistent Methodology. In: Selected Poster Prepared for Presentation at the Agricultural & Applied Economics Association's 2013 AAEA & CAES Joint Annual Meeting, Washington DC.

Balasuadhkar, A., Fisseha, T., Atenafo, A., and Bino, B. (2016). A review on passive solar dryers for agricultural products, *International Journal for Innovative Research in Science & Technology*, 3 (1), 64-70.

Bantayehu, M., Alemayehu, M., Abera, M., and Bizuayehu, S. (2019) 'Estimation of pre and postharvest losses of tropical fruits in Ethiopia', *International Journal of Postharvest Technology and Innovation*, 6 (1), 46–56.

Bart, M., Seneshaw, T., and Thomas, R. (2021). Post-harvest losses in rural-urban value chains: Evidence from Ethiopia. *Food Policy*, 98, 101860. doi: 10.1016/j.foodpol.2020.101860.

Bateman, I. J., Carson, R. T., Day, B., Hanemann, M., Hanley, N., Hett, T., and Pearce, D. W. (2002). *Economic Valuation with Stated Preference Techniques: A Manual*. Edward Elgar Publishing Ltd, Cheltenham, UK.

Bator, F. M. (1958). The anatomy of market failure. *Quarterly Journal of Economics*, 72 (3), 351- 379.

Batz, F.-J., Janssen, W., and Peters, K. J. (2003). Predicting technology adoption to improve research priority – setting. *Journal of Agricultural Economics*, 28, 151-164.

Belik, W. (2018). Impasses in transformation of the food system. *Future of Food: Journal of Food, Agriculture and Society*, 6 (2), 5–8.

Bokusheva, R., Finger, R., Fischler, M., Berlin, R., Marín, Y., Pérez, F., and Paiz, F. (2012). Factors determining the adoption and impact of a postharvest storage technology. *Food Security*, 4, 279–293. https://doi.org/10.1007/s12571-012-0184-1

Box, G. E. P., and Cox, D. R. (1964). An analysis of transformations. *Journal of the Royal Statistical Society: Series B*, 26, 211–252. https://doi.org/10.1111/j.2517-6161.1964.tb00553.x

Boyle, K., Michael, P. W., and Bishop, R. (1988). Validation of empirical measures of welfare change. *Land Economics*, 64 (1), 94-98.

Braunschweig, T. (2000). Priority Setting in Agricultural Biotechnology Research: Supporting Public Decisions in Developing Countries with the Analytic Hierarchy Process. ISNAR Research Report No. 16. The Hague: International Service for National Agricultural Research.

Brecht, J. K., Sargent, S. A., Kader, A. A., Mitcham, E. J., Maul, F., Brecht, P. E., and Menocal, O. (2020). Mango Postharvest Best Management Practices Manual, National Mango Board, UC Davis, USA. https://edis.ifas.ufl.edu/pdffiles/HS/HS118500.pdf

Broadman, A. E., Greenberg, D. H., Vining, A. R., and Veimer, D. L. (2001). *Cost-benefits analysis: Concepts and Practice*. Upper Saddle River, Prentice Hall, New York.

Brun, F. (2002). Multifunctionality of Mountain Forests and Economic Evaluation. *Forest Policy and Economics, 4*(2), 101-112.

Bundi, A., Mburu, J., Mbogoh, S. G., and Ambuko, J. L. (2020). Factors influencing the adoption of pre-harvest practices among mango farmers in Embu and Machakos counties, Kenya. *International Journal of Postharvest Technology and Innovation,* 7 (1), 56-72. https://doi.org/10.1504/IJPTI.2020.108744

Bundi, M. K., Nzuma, J., and Mbatia, O. L. E. (2013). Urban demand for smallholder crops; the case of fruits and vegetables in Nairobi, Kenya. A paper presented at the 4th international conference of the African association of agricultural economists, 22-25 September Hammamet, Tunisia

Carroll, J., McCarthy, S., and Newman, C. (2006). An econometric analysis of charitable donation. *The Economic and Social Review*. 36 (3), 229-249.

Catalano, G., Florio, M., and Giffoni, F. (2016). Willingness to pay for basic research: A contingent valuation experiment on the large hardon collider. Paper produced in the frame of the research project '*Cost/Benefit Analysis in the Research, Development and Innovation Sector'* sponsored by the EIB University Research Sponsorship programme (EIBURS).

Centre for the Promotion of Imports from developing countries (CBI). (2016). Exporting fresh exotic tropical fruit to Europe. Retrieved March 23, 2020, from https://www.cbi.eu/node/1890/pdf

Centre for the Promotion of Imports from developing countries (CBI). (2017). Exporting mangoes to Europe. Retrieved January 30, 2020, from https://www.cbi.eu/market-information/fresh-fruit-vegetables/mangoes-0

Centre for the Promotion of Imports from developing countries (CBI). (2020). The European market potential for dried tropical fruit. Retrieved December 15, 2020, from https://www.cbi.eu/node/1250/pdf

Channa, H., Chen, A. Z., Pina, P., Pina, J. R., and Stein, D. (2019). What drives smallholder farmers' WTP for a new farm technology? Evidence from an experimental auction in Kenya. *Food Policy*, 85, 64-71. https://doi.org/10.1016/j.foodpol.2019.03.005

Chappalwar, A. M., Pathak, V., Goswami, M., and Verma, A. K. (2020). Development of functional chicken patties with incorporation of mango peel powder as fat replacer. *Nutrition & Food Science*, 3(1), 6625-6659

Chia, S. Y., Macharia, J., Diiro, G. M., Kassie, M., Ekesi, S., van Loon, J. A., Dicke, M., and Tanga, C. M. (2020). Smallholder farmers' knowledge and willingness to pay for insect-based feeds in Kenya. *PLoS One*, 15(3), e0230552. https://doi.org/10.1371/journal.pone.0230552

Chikez, H., Maier, D., and Sonka, S. (2021). Mango Postharvest Technologies: An Observational Study of the Yieldwise Initiative in Kenya. *Agriculture*, 11 (7), 623-679. https://doi.org/10.3390/ agriculture11070623

Chiu, Y., Williams, P. L., Gillman, M. W., Hauser, R., Rifas-Shiman, S. L., Bellavia, A., and Chavarro, J. E. (2018). Maternal intake of pesticide residues from fruits and vegetables in relation to foetal growth. *Environmental International*, 119, 421-428. https://doi.org/10.1016/j.envint.2018.07.014.

Cochran, W. G. (1963). Sampling Techniques (2nd ed.). New York : John Wiley & Sons Inc.

Cummings, R. G., Schulze, W. D., Gerking, S. D., and Brookshire, D. S. (1986). Measuring the elasticity of substitution of wages for municipal infrastructure: A comparison of the survey and wage hedonic approaches. *Journal of Environment and Economic Management*, 13 (3), 269-276. https://doi.org/10.1016/0095-0696(86)90027-6

Dalmau-Matarrodona, E. (2001). Alternative Approaches to obtain optimal bid values in contingent valuation studies and to model protest zeros. Estimating the determinants of individual's willingness to pay for home care services in day case surgery. *Health Economics*, 16, 101-118.

Deaton, A. S., and Irish, M. (1984). Statistical models for zero expenditures in household budgets. *Journal of Public Economics*, 23, 59-80. https://doi.org/10.1016/0047-2727(84)90067-7

Debass, T. (2000). *Economic Impact Assessment of IPM CRSP Activities in Bangladesh and Uganda: A GIS Application.* MSc thesis, Virginia Polytechnic Institute and State University.

Demont, M., Rodenburg, J., Diagne, M., and Diallo, S. (2009). *Ex ante* impact assessment of herbicide resistant rice in the Sahel. *Crop Protection*, 28, 728-730.

Dogan, N., and Adanacioglu, H. (2022). Consumers' willingness to pay for traditional products with geographical indication: a case study on pestil from Gümüşhane, Turkey. *Food science and technology*, 42, e41621.

Dong, W. (2019). A case study on Chinese consumers' willingness to pay for geographical indication products. *The Frontiers of Society. Science and Technology*, 1(7), 95-103.

Donkor, E., Onakuse, S., Bogue, J., and de los Rios Carmenado, I. (2018). Promoting value addition among farmers in the cassava food value chain in Nigeria. *British Food Journal,* 120 (9), 2047-2065.

Ecker, O., and Qaim, M. (2008). Income and price elasticities of food demand and nutrient consumption in Malawi. Paper presented at the American agricultural economics association annual meeting, Orlando, FL.

Elemasho, M. K., Alfred, S. D. Y., Aneke, C. C., Chugali, A. J. C., and Ajiboye, O. **(**2017a). Factors affecting adoption of post-harvest technologies of selected food crops in Rivers State, Nigeria. *International Journal of Agricultural Economics and Extension*, 5 (5), 295-301.

Elemasho, M. K., Alfred, S. D. Y., Aneke, C. C., Chugali, A. J. C., and Ajiboye, O. **(**2017b). Farmers' perception of adoption of postharvest technologies of selected food crops in Rivers State, Nigeria. *International Journal of Agricultural Research, Innovation and Technology*, 7 (1), 22-26.

Euromonitor International (2007). Consumer Foodservice – World. London: Euromonitor International. Retrieved December 15, 2019, from http://www.gmid.euromonitor.com.

Fernandez, C., Leon, C. J., Steel, M. F. J., and Polo, F. J. V. (2004). Bayesian analysis of interval data contingent valuation models and pricing policies. *Journal of Business and Economic Statistics,* 22 (4), 431-442. https://doi.org/10.1198/073500104000000415

FANRPAN. (2017). Cost Benefit Analysis of Post-Harvest Management Innovations Benin Case Study. FANRPAN, Pretoria, South, Africa.

FAO/WHO. (2005). Practical actions to promote food safety: regional conference on food safety for Africa, final report. Retrieved December 2, 20202, from http://www.fao.org/3/a-a0215e.pdf

FAO. (2012). World agriculture towards 2030/2050: the 2012 revision. Food and Agriculture Organization of the United Nations, Rome, Italy. https://www.fao.org/3/ap106e/ap106e.pdf

FAO. (2014a). *Food losses and waste in the context of sustainable food systems*. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. FAO, Rome.

FAO. (2014b). Kenya Food Loss Assessments: Causes and Solutions. Case Studies in Small-scale Agriculture and Fisheries Subsectors. FAO, Rome. http://www.fao.org/fileadmin/user_upload/savefood/PDF/Kenya_Food_Loss_Studies.pdf

FAO. (2014c). The Spectrum of malnutrition. Retrieved September 3, 2020, from http://www.fao.org/worldfoodsummit/english /fsheets /malnutrition.pdf

FAO. (2015). Global initiative on food loss and waste reduction. FAO, Rome. Retrieved 20 January 2020, from http://www.fao.org/3/a-i4068e.pdf

FAO. (2017). The state of food security and nutrition in the world. Building resilience for peace and food security. FAO, Rome. Retrieved 15 August 2020, from http://www.fao.org/3/i7695en/i7695en.pdf

FAO. (2018). Food Loss Analysis: Causes and Solutions Case Study on the Mango Value Chain in the Republic Of Trinidad and Tobago. FAO, Rome. http://www.fao.org/3/I9569EN/i9569en.pdf

FAO. (2019a). The State of Food and Agriculture 2019: Moving Forward on Food Loss and Waste Reduction. FAO, Rome.

FAO. (2019b). The state of food security and nutrition in the World: Safeguarding against economic slowdowns and downturns. FAO, Rome.

FAO. (2020). The state of food security and nutrition in the world 2020. Transforming food systems for affordable healthy diets. FAO, Rome. Retrieved 20 June 2020, from http://www.fao.org/3/ca9692en/ca9692en.pdf

FAO. (2021). The state of food security and nutrition in the world. Transforming food systems for food security, improved nutrition and affordable healthy diets for all. Food and Agriculture Organization of the United Nations, Rome, Italy. https://www.fao.org/3/cb4474en/cb4474en.pdf

FAOSTAT (The FAO Statistical Database). (2021). Mango production in Africa. Retrieved March 3, 2021, from http://www.fao.org/faostat/en/#data/QC

Gashaw, B. A., Habteyesus, D. G., and Nedjo, Z. S. (2018). Determinants of coffee value addition by smallholder farmers in Jimma Zone, Ethiopia. The International *Journal of Business Management and Technology*, 2(8), 112-123.

Genkinger, J. M., Platz, E. A., Hoffman, S. C., Comstock, G. W., and Helzlsouer, K. (2004). Fruit, vegetable, and antioxidant intake and all-cause cancer. And cardiovascular disease mortality in a community-dwelling population in Washington County.

Maryland. *American Journal of Epidemiology*, 160 (12), 1223-1233. https://doi.org/10.1093/aje/kwh339

GIZ. (2013). Reducing postharvest losses conserves natural resources and saves money. Report of GFFA expert panel discussion held on 18 January 2013 in Berlin.

Giblin, T., and Mathews, A. (2005). Global and EU agricultural trade reform: what is in it for Tanzania, Uganda and Sub-Saharan Africa? IIIS Discussion Paper No. 74.

GoK (Government of Kenya). (2008). Economic Survey. Ministry of Planning and Vision 2030, Nairobi, Kenya.

GoK. (2011). National Food and Nutrition Security Policy. Nairobi, Kenya.

GoK. (2018). Climate risk profile Machakos. Kenya county climatic risk profile series: The Kenya ministry of agriculture, livestock and fisheries, Nairobi, Kenya.

GoK. (2019). Agricultural Sector Transformation and Growth Strategy. Ministry of Agriculture, Livestock and Fisheries, Nairobi, Kenya.

Grant, W., Kadondi, E., Mbaka, M., and Ochieng, S. (2015). Opportunities for financing the mango value chain: A case study of lower Eastern Kenya. FSD, Kenya. The Financial Sector Deepening Kenya (FSD Kenya) Nairobi, Kenya.

Greene, W. H. (2002). *Econometric Analysis*, fifth ed. New York: Macmillan.

Greene, W. H. (2003). *Econometric Analysis*, fifth ed. New Jersey: Prentice Hall.

Greene, W. H. (2008). *Econometric Analysis*, sixth ed. Upper Saddle River, N. J.: Prentice Hall.

Griesbach J. (2003) *Mango growing in Kenya*. Nairobi: International Centre for Research in AgroForestry, World Agroforestry Centre.

Gujarati, D. (2004). Basic Econometrics, fifth ed. New York: The McGraw-Hill Companies.

Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., and Meybeck, A. (2011). Global food losses and food waste. Retrieved September 9, 2020, from http://www.fao.org/3/a-i2697e.pdf

Gyan, F. B., and Owusu, V. (2017). Consumer willingness to pay a premium for a functional food in Ghana. *Applied Studies in Agribusiness and Commerce*, 11 (1-2), 51-6

Haab, T. C., and McConnell, K. E. (2002). *Valuing Environmental Natural Resources*: *The Econometrics of Non-Market Valuation*. Northampton, MA: Edward Elgar Publishing.

Heckman, J. (1979). Sample selection bias as specification error. *Econometrica*, 47 (1), 153-162. https://doi.org/10.2307/1912352

Henning, R., and Mbithi, G. (2021). Mangoes and More – Building a Better Business Enabling Environment for Investment in Kenya's Makueni County, Marketlinks. Retrieved June 9, 2023, from https://www.marketlinks.org/blogs/mangoes-and-more-building-better-business-enabling-environment-investment-kenyas-makueni

Herriges, J. A., Kling, C. L., and Phaneuf, D. J. (2004). What's the Use? Welfare Estimates from Revealed Preference Models When Weak Complementarity Does Not Hold. *Journal of Environmental Economics and Management*, 47 (1), 55–70. https://doi.org/10.1016/S0095-0696(03)00058-5

Hicks, J. R. (1939). The foundations of welfare economics. *Economic Journal*, 49 196), 696-

712.

Hodges, R. J., Buzby, J. C., and Bennett, B. (2011). Postharvest losses and waste in developed and less developed countries: opportunities to improve resource use. *The Journal of Agricultural Science*, 149 (S1), 37-45. https://doi.org/10.1017/S0021859610000936

Homburg, C., Klarmann, M., and Schmitt, J. (2010). Brand awareness in business markets: When is it related to firm performance. *International Journal of Research in Marketing*. 27, 201–212. https://doi.org/10.1016/j.ijresmar.2010.03.004

HCDA (Horticultural Crop Development Authority). (2014). Horticulture Validated Report, Ministry of Agriculture, Kenya.

HCD (Horticultural Crop Directorate). (2017). *Horticulture Validated Report*, Ministry of Agriculture, Kenya.

HCD. (2020). *Horticulture Validated Report*, Ministry of Agriculture, Kenya.

Hudson, D., and Hite, D. (2003). Producer willingness to pay for precision application technology: implications for government and the technology industry. *Canadian Journal of Agricultural Economics*, 51, 39-53. https://doi.org/10.1111/j.1744-7976.2003.tb00163.x

Humble, S., and Reneby, A. (2014). *Post Harvest Losses in Fruit Supply Chains – A Case Study of Mango and Avocado in Ethiopia*. Msc thesis, Swedish University of Agricultural Sciences.

Hunt, E. K., and Lautzenheiser, M. (2011). History of Economic Thought: A Critical Perspective (3rd Ed.). Armonk, New York: M. E. Sharpe.

Irungu, P. (2011). An economic analysis of adoption potential of new tsetse fly repellent technology in trypanosomosis control: The case of Kajiado and Narok Districts of Kenya. PhD. thesis, University of Nairobi.

Jabs, J., and Devine, C. M. (2006). Time scarcity and food choice: An overview. *Appetite*, 47, 196- 204. https://doi.org/10.1016/j.appet.2006.02.014

Jaeger, S. (2006). Non–sensory factors in sensory science research. *Food Quality and Preference Journal*, 17, 132-144. https://doi.org/10.1016/j.foodqual.2005.03.004

Jesionkowska, K., Sijtsema, S. J., Konopacka, D., and Symoneaux, R. (2009). Dried fruit and its functional properties from a consumer's point of view. *Journal of Horticultural Science and Biotechnology*, 84 (6), 85-88. https://doi.org/10.1080/14620316.2009.11512601

Jesionkowska, K., Sijtsema, S. J., Simoneaux, R., Konopacka, D., and Plocharski, W. (2008). Preferences and consumption of dried fruit and dried fruit products among Dutch, French and Polish consumers. *Journal of Fruit and Ornamental Plant Research*, 16, 261-274.

Jha, S. N. (2008). Development of a pilot scale evaporative cooled storage structure for fruits and vegetables for hot and dry region. *Journal of Food Science and Technology*, 45 (2), 148–151.

Jones, A.M. (1989), "A double-hurdle model of cigarette consumption", Journal of Applied Econometrics, vol. 4, pp. 23-39

Kader, A. A. (2005). Increasing food availability by reducing postharvest losses of fresh produce. *Acta Horticulturae*, 682, 2169-2176. https://doi.org/10.17660/ActaHortic.2005.682.296

Kader, A. A. (2009). Handling of horticultural perishables in developing vs. developed countries. VI International Postharvest Symposium 877, 121-126.

Kahwai, J. N., Mburu, J. I., Oulu, M. O., Hutchinson, M. J. (2021). Willingness to pay for hexanal technology among banana farmers in Meru County, Kenya. *International Journal of Food Science*, 879, 1-10. http://dx.doi.org/10.1155/2021/6676148

Kaldor, N. (1939). Welfare propositions of economics and interpersonal comparisons of utility. *Economic Journal*, 49(195), 549–552.

Kaliba, A. R., Verkuijl, H., and Mwangi, W. (2000). Factors affecting adoption of improved maize seeds and use of inorganic fertilizer for maize production in the intermediate and lowland zones of Tanzania. *Journal of Agricultural and Applied Economics*, 32 (01), 35-47. https://doi.org/10.1017/S1074070800027802

Kalpana, R., Khan, M. K., and Sahoo, N. R. (2010). Water use optimization in zero energy cool chambers for short term storage of fruits and vegetables in coastal area. *Journal of Food Science and Technology*, 47(4), 437–441.

Karithi, E. M. (2016). Evaluation of the efficacy of coolbot™ cold storage technology to preserve quality and extend shelf life of mango fruits. MSc thesis, University of Nairobi.

Karl, M. R., Holst, D. R., and Otte. J. (2012). An assessment of the socio-economic impacts of global rinderpest eradication – Methodological issues and applications to rinderpest control programmes in Chad and India. FAO Animal Production and Health Working Paper No. 7. Rome.

Kassie, M., Marenya, P., Tessema, Y., Jaleta, M., Zeng, D., Erenstein, O., and Rahut, D. (2018a). Measuring farm and market level economic impacts of improved maize production technologies in Ethiopia: evidence from panel data. *Journal of Agricultural Economics*, 69 (1), 76–95. https://doi.org/10.1111/1477-9552.12221

Kassie, M., Stage, J., Diiro, G., Muriithi, B., Muricho, G., Ledermann, S. T., Pittchar, J., Midega, C., and Zeyaur, K. (2018b). Push–pull farming system in Kenya: Implications for economic and social welfare. *Land Use Policy*, 77, 186-198.

https://doi.org/10.1016/j.landusepol.2018.05.041

Katoch, P., Katoch, A., and Dangi, B. (2019). An Overview on Mango Malformation and the Potential Approaches to Their Management. *Journal of Pharmacognosy and Phytochemistry*, 8 (4), 621 – 626.

Kayier, G., Amsale, W., and Beshadu, S. (2019). A review on production and marketing of mango fruit. *World Journal of Agriculture and Soil Science*, 2(2),1–12. doi: 10.33552/WJASS.2019.02.000533.

Kayisoglu, S., and Coskun, F. (2016). Determination of the level of knowledge of consumers about food additives. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 10 (8), 53-56. https://doi.org/10.9790/2402-1008015356

KALRO. (2021). Climate Smart Agriculture Technologies, Innovations and Management Practices for Mango Value Chain. Training of trainer’s manual. KALRO, Nairobi, Kenya.

KNBS. (2019a). Kenya population and housing census: Vol 1 Population by county and sub-county. Retrieved March, 5, 2021, from https://www.knbs.or.ke/?wpdmpro=2019-kenya-population-and-housing-census-volume-i-population-by-county-and-sub-county

KNBS (2019b). 2019 Kenya Population and Housing Census. Vol. IV. Distribution of Population by Socio-economic Characteristics.

Kessy, R. F., Ochieng, J., Afari-Sefa, V., Chagomoka, T., and Nenguwo, N. (2018). Solar-dried traditional African vegetables in rural Tanzania: Awareness, perceptions, and factors affecting purchase decisions. *Economic Botany*, 72**,** 367–379. https://doi.org/10.1007/s12231-018-9434-2

Khan, F. A., Bhat, S. A., and Narayan, S. (2017). Storage Methods for Fruits and Vegetables. Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India.

Kikulwe, E. M., Okurut, S., Ajambo, S., Nowakunda, K., Stoian, D., and Naziri, D. (2018). Postharvest losses and their determinants: A challenge to creating a sustainable cooking banana value chain in Uganda. *Sustainability*, 10 (7), 2381.

https://doi.org/10.3390/su10072381

Kimenju, S. C., and De Groote, H. (2010). Economic analysis of alternative maize storage technologies in Kenya. Paper presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, 19-23 September, Cape Town, South Africa

Kimiywe, J. (2015). Food and nutrition security : challenges of postharvest handling in Kenya. In Proceedings of the Nutrition Society, 74 (4) 487-495.

Kitinoja, L, (2010). Identification of appropriate postharvest technologies for improving market access and incomes for small horticultural farmers in Sub-Saharan Africa and South Asia. WFLO Grant Final Report; 323

Kitinoja, L. (2013). Innovative small-scale postharvest technologies for reducing losses in horticultural crops. *Ethiopian Journal of Applied Science and Technology*, 1, 9-15.

Kitinoja, L., Saran, S., Roy, S. K., and Kader, A. A. (2011). Postharvest Technology for Developing Countries: Challenges and Opportunities in Research, Outreach and Advocacy. *Journal of the Science of Food and Agriculture,* 91, 597– 603.

https://doi.org/10.1002/jsfa.4295

Kristjanson, P. M., and Zerbini, E. (1999). Genetic enhancement of sorghum and millet residues fed to ruminants. An ex ante assessment of returns to research. ILRI impact assessment series 3. ILRI, Nairobi, Kenya. Available at: cgspace.cgiar.org/bitstream/handle/10568/497/Impact3.pdf

Kunyanga, C., Amimo, J., Njue, L. K., and Chemining'wa, G. (2018). Consumer risk exposure to chemical and microbial hazards through consumption of fruits and vegetables in Kenya. *Food Science and Quality Management*, 78, 59-69.

Kwak, S.-Y., Yoo, S.-H., and Kim, C.-S. (2013). Measuring the willingness to pay for tap water quality improvement. Results of a contingent valuation survey in Pusan. *Water*, 5,1638-1652. https://doi.org/10.3390/w5041638

Lancaster, K. J. (1966). A new approach to consumer theory. *Journal of Political Economy*, (2), 132-157. https://doi.org/10.1086/259131

Lera-Lopez, F., Faulin, J., Sanchez, M., and Serrano, A. (2014). Evaluating factors of the willingness to pay to mitigate the environmental effects of freight transportation crossing the Pyrenees. *Transportation Research Procedia*, 3, 423-432. https://doi.org/10.1016/j.trpro.2014.10.023

Liebe, U., Preisendörfer, P., and Meyerhoff, J. (2010). To Pay or Not to Pay: Competing Theories to Explain Individuals' Willingness to Pay for Public Environmental Goods. *Environment and Behavior*, 43(1), 106-130

Maalouf, A., and Chalak, A. (2019). Farmers’ willingness to pay for operating a collective postharvest refrigeration unit in an eastern Mediterranean rural community. *Journal of Agriculture, Food Systems, and Community Development*, 9(1), 89–99. https://doi.org/10.5304/jafscd.2019.091.012

Maldonado - Celis, M. E., Yahia, E. M., Bedoya, R., Landázuri, P., Loango, N., Aguillón, J., Restrepo, B., and Guerrero Ospina, J. C. (2019). Chemical Composition of Mango (Mangifera indica L.) Fruit: Nutritional and Phytochemical Compounds. *Frontiers in Plant Science*, 10, 1-21.

Maloba, S., Ambuko, J., Hutchinson, M., and Owino, W. (2017). Off-season flower induction in mango fruits using ethephon and potassium nitrate. *Journal of Agricultural Science*, 9 (9), 158-167.

Manyozo, F. N., Ambuko, J., Hutchinson, M. J., and Kamanula, J. F. (2018). Effectiveness of evaporative cooling technologies to preserve the postharvest quality of tomato. *International Journal of Agronomy and Agricultural Research*, 13 (2), 114-127

Marconi1, V., Raggi, M., Viaggi, D., Lefebvre, M., and Paloma, S. G. (2015). The impact of the 2013 common agricultural policy reform on farmer's investment decisions: an ex-ante evaluation. *A paper presented at the International association of agricultural economists conference, Milan, Italy, Aug 8-14.*

Maredia, M., Byerlee, D., and Anderson, J. (2000). *Ex post* evaluation of economic impacts of agricultural research programs: A tour of good practice. A paper presented to the workshop on "The future of impact assessment in CGIAR: Needs, constraints and options", from 3rd to 5th May 2000, Rome, Italy.

Marshall, A. (1920). *Principles of economics*. , London: MacMilIan

McFadden, D. (1974). Conditional Logit Analysis of Qualitative Choice Behaviour. P. E. Zarembka, ed., Frontiers of Econometrics. New York: Academic Press.

Mengistie, M., Alemseged, G., Zemen, A., and Asres, E. (2021). Food security effects of smallholders' participation in apple and Mango value chains in north-western Ethiopia. *Agriculture and Food Security,* 10(47), 1–15. doi: 10.1186/ s40066-021-00310-z.

Migwi, B., Mutegi, C., Mburu, J., Wagacha, J., Cotty, P., Bandyopadhyay, R., and Manyong, V. M. (2020). Assessment of willingness-to-pay for Aflasafe KE01, a native biological control product for aflatoxin management in Kenya. *Food additives & contaminants*, 37 (11), 1951-1962.

Molotoks, A., Stehfest, E., Doelman, J., Albanito, F., Fitton, N., Dawson, T. P., and Smith, P. (2018). Global projections of future cropland expansion to 2050 and direct impacts on biodiversity and carbon storage. *Global Change Biology*, 24(12), 5895-5908.

Moussa, B., Lowenberg-DeBoer, J., Fulton, J., and Boys, K. (2011). The economic impact of cowpea research in West and Central Africa: A regional impact assessment of improved cowpea storage technologies. *Journal of Stored Products Research*, 47, 147-156. https://doi.org/10.1016/j.jspr.2011.02.001

Mrema, G. C., and Rolle, R. S. (2002). Status of the postharvest sector and its contribution to agricultural development and economic growth, p. 13–20. In: Proceedings of the 9th JIRCAS International Symposium held from 8th October to 4th November 2020. Tsukuba, Japan.

Muchiri, D. R., Mahungu, S. M., and Gituanja, S. N. (2012). Studies on mango (*Mangifera indica*, L.) Kernel fat of some Kenyan varieties in Meru. *Journal of the American Oil Chemists' Society,* 89,1567-1575. https://doi.org/10.1007/s11746-012-2054-6

Mujuka, E. A., Affognon, H., Muriithi, B. W., Subramanian, S., Irungu, P., and Mburu, J. (2017). Returns to research and outreach for integrated pest management of western flower thrips infesting French bean and tomato in Kenya. *International Journal of Tropical Insect Science*, 37 (2),114-124. https://doi.org/10.1017/S1742758417000029

Mujuka, E., Mburu, J., Ogutu, A., and Ambuko. J. (2019). Returns to investment in postharvest loss reduction technologies among mango farmers in Embu County, Kenya. *Food and Energy Security*, 9 (1). https://doi.org/10.1002/fes3.195

Mujumdar, A. S. (2007 *Handbook of Industrial drying*, ed. T.a.F. group. UK: Taylor and Francis group.

Mulinge, W. K., Kimiti, J. M., Muasya, R. M., and Akuja, T. E. (2015). Grafted mangoes enhances smallholder farmers livelihoods in Matinyani Division, Kitui County. *Journal of Biology, Agriculture and Healthcare*, 5(16),60–65.

Mungai, J. K., Ouko, J., and Heiden, M. (2000). Processing of fruits and vegetables in Kenya. Marketing Information Branch, Ministry of Agriculture and Rural Development. Agricultural Information Centre. Nairobi. Kenya

Musyoka, J. K., Isaboke, H. N., and Ndirangu, S. N. (2020). Farm-level value addition among small-scale mango farmers in Machakos County, Kenya. *Journal of Agricultural Extension*, 24 (3). https://dx.doi.org/10.4314/jae.v24i3.8

Muthini, D. N., Nyikal, R. A., and Otieno, D. J. (2017). Determinants of small-scale mango farmers' market channel choices in Kenya: An application of the two-step Cragg's estimation procedure. *Journal of Development and Agricultural Economics,* 9 (5),111-120.

Mwaijande, F. (2017). Farmers' adoption and willingness to pay for postharvest technologies in Tanzania: Policy implication for enhancing food security. *Journal of postharvest Technology*, 5 (1),1-6.

Mwaura, F., Muwanika, F. R., and Okoboi, G. (2010). Willingness to pay for extension services in Uganda among farmers involved in crop and animal husbandry. *A Paper presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, September 19-23, 2010.*

Mwende, N. (2022). Makueni diversifies fruit value addition to save collapsing processing plant and catalyse the rural economy. Retrieved June 5, 2023, from https://maarifa.cog.go.ke/county-initiatives/makueni-diversifies-fruit-value-addition-save-collapsing-processing-plant-and

Mwebaze, P., and Mugisha, J. (2011). Adoption, utilization and economic impacts of improved postharvest technologies in maize production in Kapchorwa District, Uganda. *International Journal of Postharvest Technology and Innovation*, 2 (3),301-327. https://doi.org/10.1504/IJPTI.2011.043328

Neven, D., Reardon, T., Chege, J., and Wang, H. (2006). Supermarkets and consumers in Africa: the case of Nairobi, Kenya. *Journal of International Food and Agribusiness Marketing*, 18, 1-2.

Ngasoh, F. G., Anyanwu, C. N., Namessan, N. O., Ahmadu, A. A., and Suleiman, M. A. (2018). An overview of solar fruit drying: A potential remedy for postharvest losses in Nigeria. *International Research Journal of Engineering and Technology*, 5 (4), 3559-3568.

Ngigi, M. W., Okello, J. J., Lagerkvist, C. L., Karanja, N. K., and Mburu, J. (2011). Urban consumers' willingness to pay for quality of leafy vegetables along the value chain: the case of Nairobi kale consumers, Kenya. *International Journal of Business and Social Science*, 2 (7), 208-216.

Ntale, D. J. F., Litondo, D. K. O., and Mphande, M. O. M. (2015). Indicators of value added agri-businesses on small farms in Kenya: An empirical study of Kiambu and Murang'a Counties. *Journal of Small Business and Entrepreneurship Development,* 2(4), 89-101.

Ntsoane, M. L., Sivakumar, D., and Mahajan, P. V. (2020). Optimisation of O2 and CO2 concentrations to retain quality and prolong shelf life of ‘shelly’ mango fruit using a simplex lattice mixture design. Biosystems Engineering, 192, 14–23. doi: 10.1016/j.biosystemseng.2020.01.009

Ntsoane, M. L., Zude-Sasse, M., Mahajan, P., and Sivakumar, D. (2019). Quality assesment and postharvest technology of mango: a review of its current status and future perspectives. *Scientia Horticulturae*, 249, 77–85. doi: 10.1016/j.scienta.2019.01.033

O'Brien, B., and Viramontes, J. L. (1994). Willingness to pay: A valid and reliable measure of health state preference? *Medical Decision Making*, 14, 289-297. https://doi.org/10.1177/0272989X9401400311

Ogumo, E. O., Kunyanga, C. N., Okoth, M. W., and Kimenju, J. (2017). Current knowledge in performance of existing charcoal coolers in improving the overall quality and shelf-life of French beans. *African Journal of Agricultural Research,* 12 (49), 3399-3409

https://doi.org/10.5897/AJAR2017.12749

Okello, J. J., Hutchinson, M. J., Mwang’ombe, A., Ambuko, J., Olubayo, F., and Mwakangalu, M. (2015). Consumer demand for value-added products of African indigenous vegetables in coastal Kenya: The case of sundried and frozen cowpea leaves. *Journal of Agriculture, Food Systems, and Community Development,* 1–18. https://doi.org/10.5304/jafscd.2015.061.004

Okoffo, E. D., Denkyirah, E. K., Adu, D. T., and Fosu-Mensah, B. Y. (2016). A double-hurdle model estimation of cocoa farmers’ willingness to pay for crop insurance in Ghana. *SpringerPlus, 5*, 873. doi:10.1186/s40064-016-2561-2

Opara, L. U., Fahad, A. A., and Aamna, A. (2007). Assessment of what the consumer values in fresh fruit quality: case study of Oman. *New Zealand Journal of Crop and Horticultural Science,* 35 (2), 235-243. https://doi.org/10.1080/01140670709510190

Ortiz-Garcıa-Carrasco, B., Yanez-Mota, E., Pacheco-Aguirre, F. M., Ruiz-Espinosa, H., Garcia- Alvarado, M. A., Cortes-Zavaleta, O., and Ruiz-Lopez, I. I. (2015). Drying of shrinkable food products: appraisal of deformation behavior and moisture diffusivity estimation under isotropic shrinkage. *Journal of Food Engineering*, 144 (2015), 138–147. https://doi.org/10.1016/j.jfoodeng.2014.07.022

Osena, E. D. (2011). An analysis of the mango fruit value chain in Embu. MSc. thesis, University of Nairobi.

Otieno, D. J., and Nyikal, R. A. (2017). Analysis of consumer preferences for quality and safety attributes in artisanal fruit juices in Kenya. *Journal of Food Products Marketing,* 23 (7), 817-834. https://doi.org/10.1080/10454446.2016.1164103

Owureku-Asare, M., Ambrose, R. P. K., Oduro, I., Tortoe, C., and Saalia, F. K. (2017). Consumer knowledge, preference, and perceived quality of dried tomato products in Ghana. *Food Science and Nutrition*, 5, 617–624. https://doi.org/10.1002/fsn3.439

Panda, R., and Sreekumar. (2012). Marketing Channel Choice and Marketing Efficiency Assessment in Agribusiness. *Journal of International Food & Agribusiness Marketing*, 24 (3), 213-230. https://doi.org/10.1080/08974438.2012.691812

Pardey, P. G., Andrade, R. S., Hurley, T. M., Rao, X., and Liebenberg, F. G. (2016). Returns to food and agricultural R & D investments in Sub-Saharan Africa, 1975 – 2014. *Food Policy*, 65, 1-8.

Pareto, V. (1896). *Coursd'EconomiePolitique*, Vol. 2, F. Rouge, Lausanne.

Pareto, V. F. D. (1966). *Manuel d'economie politique.* Geneve; originally published by Girard et Briere, Paris.

Parfitt, J., Barthel, M., and Macnaughton, S. (2010). Review Food waste within food supply chains: quantification and potential for change to 2050. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 365 (1554), 3065-3081.

Perman, R., Ma, Y., McGilvray, J., and Common, M. (2003). *Natural Resources and Environmental Economics*. Third Edition. The Great Britain: Pearson Education Limited,

Perraton, H., Jamison, D. T., Jenkins, J., Orivel, F., and Wolft, L. (1983). Basic Education and Agricultural Extension: Costs, Effects, and Alternatives. Staff Working Paper 564. World Bank, Washington, DC.

Perumal, A. B., Nambiar, R. B., Sellamuthu, P. S., and Emmanuel, R. S. (2021). Use of modified atmosphere packaging combined with essential oils for prolonging post-harvest shelf life of mango (cv. Banganapalli and cv. Totapuri). *LWT*, 148, 111662. doi: 10.1016/j.lwt.2021.111662

Pigou, A. C. (1952). *The economics of welfare*. London: MacMilIan.

Pugh, T. A. M., Müller, C., Elliott, J., Deryng, D., Folberth, C., Olin, S., Schmid, E., and Arneth, A. (2016). Climate analogues suggest limited potential for intensification of production on current croplands under climate change. *Nature Communications*, 7, 1–8.

Rababah, T. M., Ereifej, K. I., and Howard, L. (2005). Effect of ascorbic acid and dehydration on concentrations of total phenolics, antioxidant capacity, anthocyanins, and color in fruits. *Journal of Agricultural and Food Chemistry*. 53, 4444–4447. https://doi.org/10.1021/jf0502810

Ready, R. C., Buzby, J. C., and Hu, D. Y. (1996). Differences between continuous and discrete contingent value estimates. *Land Economics*, 72 (3), 397-411.

Regassa, S. (2014). Does it pay to invest in postharvest management? An ex-ante cost benefit analysis of reducing maize storage losses in Darimu Woreda, Ethiopia. Swiss agency for development and cooperation report, Addis Ababa.

Reynolds, C., Goucher, L., Quested, T., Bromley, S., Gillick, S., Wells, V.K., Evans, D., Koh, L., Carlsson Kanyama, C., Katzeff, A., Svenfelt, Å., and Jackson, P. (2019). Review: consumption-stage food waste reduction interventions – what works and how to design better interventions. *Food Policy*, 83, 7 – 27.

RF. (2020). Making mangoes count. Global initiative on food loss and waste reduction. Rockefeller Foundation, USA. Retrieved February 15, 2020, from https://www.rockefellerfoundation.org/wp-content/uploads/2021/04/YieldWise-Mangoes-Overview-Final.pdf

Rosegrant, M. W., Paisner, M., Meijer, S., and Witcover, J. (2001). Global Food Projections to 2020: Emerging Trends and Alternative Futures, IFPRI, Washington, D.C. http://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/58741/filename/58742.pdf

Sabbe, S., Verbeke, W., and Van Damme, P. (2008). Familiarity and purchasing intention of Belgian consumers for fresh and processed tropical fruit products. *British Food Journal*, 110 (8), 805-818. https://doi.org/10.1108/00070700810893331

Salvioni, C., Henke, R., and Vanni, F. (2020). "The Impact of non-agricultural 67 diversification on financial performance. Evidence from Family Farms in Italy. *Sustainability*, 12 (2), 486.

Shee, A., Azzarri, C., and Haile, B. (2020). Farmers' willingness to pay for improved agricultural technologies: evidence from a field. *Sustainability*, 12 (1), 216. https://doi:10.3390/su12010216

Shitanda, D., Oluoch, O. K., and Pascal, A. M. (2011). Performance evaluation of a medium size charcoal cooler installed in the field for temporary storage of horticultural produce. *Agricultural Engineering International: CIGR Journal*. 13 (1), 1596.

Shukla, M., and Jharkharia, S. (2013). Agri-fresh produce supply chain management: a state-of-the-art literature review. *International Journal of Operations & Production Management*, 33 (2), 114-158.

Sijtsema, S. J., Jesionkowska, K., Symoneaux, R., Konopacka, D., and Snoek, H. (2011). Perceptions of the health and convenience characteristics of fresh and dried fruits. LWT - *LWT - Food Science and Technology*, 49 (2), 275-281. https://doi.org/10.1016/j.lwt.2012.04.027

Snel, H., Broeze, J., Kremer, F., and Osena, E. (2021). A food system analysis of Kenya's mango, avocado and poultry sectors; Assessing opportunities to reduce food losses. Wageningen Centre for Development Innovation, Wageningen University & Research. Report WCDI-21-185. Wageningen.

Steve, N. (2010). Market Opportunities for Mango Growers. Kenya Horticultural Development Program 2004-2010. USAID, Kenya.

Suntharalingam, C., and Terano, R. (2017). Factors influencing consumption decision of fresh fruits from Malaysia: A case of foreign nationals in Malaysia. International *Food Research Journal*, 24 (4), 1437-1444.

Swinburn, B. A., Sacks, G., Hall, K. D., McPherson, K., Finegood, D. T., Moodie, M. L., and Gortmaker, S. L. (2011). The global obesity pandemic: shaped by global drivers and local environments. *The Lancet*, 378 (9793), 804–814. https://doi.org/10.1016/S0140-6736(11)60813-1

Tarekegn, K., and Kelem, F. (2022). Assessment of Mango Post-Harvest Losses along Value Chain in the Gamo Zone, Southern Ethiopia. *International Journal of Fruit Science*, 22 (1), 170-182, DOI: 10.1080/15538362.2021.2025194

Ternent, L., and Tsuchiya, A. (2013). A note on the expected biases in conventional iterative health state valuation protocols. *Medical Decision Making*, 33, 544–546.

Thayalan, S., Priyashnatha, A. K. H., and Mahendranathan, C. (2020). A preliminary survey on postharvest challenges of small - scale farm holders of mango (Mangifera indica L) of Batticaloa District, Sri Lanka; status and requirement. *International Journal of Engineering Applied Sciences and Technology*, 4, (11), 289-295

Tilahun, S. W. (2010). Feasibility and economic evaluation of low-cost evaporative cooling system in fruit and vegetables storage. *African Journal of Food, Agriculture, Nutrition and Development*, 10 (8), 2984-2997.

Umberger, W. J., Thilmany, D., Fadden, M. C., and Amanda, R. S. (2009). Does Altruism Play a Role in Determining US Consumer Preferences and Willingness to Pay for Natural and Regionally Produced Beef? *Agribusiness*, 25 (2), 268–85. https://doi.org/10.1002/agr.20194

USAID-KAVES. (2015). Mango Value Chain Analysis. Nairobi, Kenya: USAID. Available at: https://pdf.usaid.gov/pdf_docs/PA00M2SZ.pdf.

Venkatachalam, L. (2004). The contingent valuation method: a review. *Environmental Impact Assessment Review*, 24 (1), 89-124. https://doi.org/10.1016/S0195-9255(03)00138-0

Vilane, B. R. T. (2012). Adoption of postharvest technologies used by small-holder farmers in Swaziland. *African journal of agricultural research*, 7 (35), 4983-4995. https://doi.org/10.5897/AJAR11.106

Vithana, M. D. K., Singh, Z., and Johnson, S. K. (2019). Regulation of the Levels of Health Promoting Compounds: Lupeol, Mangiferin and Phenolic Acids in the Pulp and Peel of Mango Fruit: A Review. *Journal of the Science of Food and Agriculture*, 99, 3740 – 3751.

Walsh, R. G., Loomis, J. B., and Gillman, R. A. (1984). Valuing Option, Existence, and Bequest Demands for Wilderness. *Land Economics*, 60(1), 14-29.

Wardle, J., Haase, A., Steptoe, A., Nillapun, M., Jonwutiwes, K., and Bellisie, F. (2004). Gender differences in food choice: the contribution of health beliefs and dieting. *Annals of Behavioral Medicine*, 27 (2), 107-116. https://doi.org/10.1207/s15324796abm2702_5

Wattage, P. (2002). Effective management for biodiversity conservation in Sri Lankan Coastal Wetlands: An estimation of economic value for conservation of wetlands. University of Portsmouth, Portsmouth, England.

Wayua, F. O., Okoth, M. W., and Wangoh, J. (2012). Design and Performance Assessment of a Low Cost Evaporative Cooler for Storage of Camel Milk in Arid Pastoral Areas of Kenya. *International Journal of Food Engineering,* 8 (1), 16.

Wei, S., Mei, J., and Xie, J. (2021). Effects of different carbon dioxidemodified atmosphere packaging and low-temperature storage at 13?c on the quality and metabolism in mango (Mangifera indica L.). *Agriculture,* 11, 636. doi: 10.3390/agriculture11070636

Whitehead, J. C. (2002). Incentive incompatibility and starting-point bias in iterative valuation questions. *Land Economics*, 78 (2), 285-97.

Whittington, D., Briscoe, J., Xinming, M., and William, B. (1990). Estimating the Willingness to Pay for Water Services in Developing Countries: A Case Study of the Use of Contingent Valuation Surveys in Southern Haiti. *Economic Development and Cultural Change,* 38 (2), 293–311. https://doi.org/10.1086/451794

Willis, K. G. (2002). Iterative bid design in contingent valuation and the estimation of the revenue maximizing price for a cultural good. *Journal of Cultural Economics*, 26, 307-324.

Wooldridge, J. M. (2000). *Introductory Econometrics: A modern approach*. South-Western College, Cincinnati, OH.

Wooldridge, J. M. 2010. *Econometric analysis of cross section and panel data*. Cambridge, MA: MIT Press.

World Bank. (2011). Missing Food: The Case of Postharvest Grain Losses in Sub-Saharan Africa. Report No. 60371 – Africa Region. Washington DC: World Bank

WHO. (2003). Expert report on diet, nutrition and the prevention of chronic disease. Retrieved June 10, 2020, from https://apps.who.int/iris/bitstream/handle/10665/42665/WHO_TRS_916.pdf?ua=1

WHO. (2013). Promoting fruit and vegetable consumption. Retrieved August 15, 2020, from http://www.euro.who.int/en/ healthtopics/diseaseprevention/nutrition/activities/technical-support-to-member-states/ promotingfruit-and-vegetable-consumption

Wu, W., Yu, Q., You, L., Chen, K., Tang, H., and Liu, J. (2018). Global cropping intensity gaps: Increasing food production without cropland expansion. *Land Use Policy*, 76, 515–525.

Yamane, T. (1967). *Statistics: An Introductory Analysis*, 2nd Edition, New York: Harper and Row.

Yu, Y. S., Luo, M., and Zhu, D. H. (2018). The effect of quality attributes on visiting consumers' patronage intentions of green restaurants. *Sustainability* 10 (4), 1187. https://doi.org/10.3390/su10041187

APPENDICES

APPENDIX 1: BASELINE SURVEY ON MANGO POSTHARVEST LOSSES

QUESTIONNAIRE S/No. ______ **COORDINATES** ______ **DATE** ______

SECTION 1: METADATA

Introductory and consent statement: "Dear Sir/Madam, I work for the University of Nairobi. I am conducting a survey to study current input-output relationships in fruit production, market dynamics, current status of postharvest losses, on-going interventions to reduce losses and stakeholders' perceptions. Your response to these questions would remain **anonymous**. Taking part in this study is voluntary. If you choose not to take part, you have the right not to participate and there will be no consequences. Thank you for your kind co-operation".

	NAME
ENUMERATOR ID	
NAME OF COUNTY	
NAME OF SUB-COUNTY	
NAME OF WARD	
NAME OF LOCATION	
NAME OF SUB-LOCATION	
NAME OF VILLAGE	
PHONE NUMBER	
TIME START	
TIME END	

SECTION 1: KNOWLEDGE, AWARENESS AND PERCEIVED ATTRIBUTES OF POSTHARVEST LOSS REDUCTION TECHNOLOGIES

1.1: TECHNOLOGIES/PRACTICES IMMEDIATELY AFTER HARVEST

1.1.1. Immediately after harvest, where do you put/place your fruits..

1.1.2. Have you adopted any of these after harvesting loss reduction technologies **(code A)** [___] 1=Yes; 0=No

CODE A*: 1= Use of crates (collapsible, wooden, bread and nest able); 2= Newspapers; 3= pallets; 4= Cartons; 5= use of shades*

1.1.3. If yes, which technology have you adopted (**Code A** above) ....

1.1.4. When did you adopt (year)..............................?

1.1.5. Why do you prefer what you have chosen to use (technology adopted) **give the most important reason.........................? (Code B)**

Code B*: 1=Less losses; 2=Availability; 3=Cheap to buy; 4=Less cost of hiring labour; 5=More market access; 6=Increases shelf life; 7=More yield; 8=More marketable produce; 9=Easy maintenance; 10=Easy to use; 11=Better market prices; 12= others (specify)........................*

1.1.6: If have **not adopted** indicate the major challenge you have been facing**? *give the most important***...................... (Code C)

Code C: *1=high cost of acquiring 2= not available 3= lack of information on use 4=cannot be used for other enterprises 5=high labour requirement 6= not easy to use 7= high cost of maintenance 8= the practice does not help me reduce post-harvest loss 9= make the work very slow, 10= am not involved in harvesting, 11= poor prices, 12= lack of market, 12= others(specify).................*

1.1.7. If have not adopted, would you like to use any of the practices in the future? [___] 1=Yes; 0=No

1.1.8: If yes give a recommendation that you would like done to facilitate your adoption…………....................................

1.1.9: For how long have you been engaged in mango production (years)? ……………………………

1.2: TECHNOLOGIES FOR STORAGE/ VALUE ADDITION

1.2.1. Are you aware of postharvest storage and value addition technologies? [___] 1=Yes; 0=No

1.2.2. If yes in 1.2.1 above, which postharvest storage and value addition technologies are you aware of? ***CODE D**: 1= Use of crates (collapsible, wooden, bread and nest able); 2= Newspapers; 3= pallets; 4= Cartons/boxes; 5= use of shades; 6=* Evaporative coolers (charcoal, coolbot, brick and MAPs; 7= aggregation centre; 8= Use of chemicals (waxing, washing with disinfectants; 9= Tunnel solar dryers 10= Aggregation centres 11=Others (specify)..........

1.2.3. Have you adopted any of these postharvest storage and value addition technologies (**code D)** [___] 1=Yes; 0=No

1.2.4. If yes, which one(s) have you adopted **(*code D above*)** ....

1.2.5. What was the cost of each?..

1.2.6. When did you adopt (year).............................?

1.2.7. Why do you prefer what you have chosen to use (technology adopted) - ***give the most important reason ………? (Code E)***

> ***Code E**: 1=Less losses; 2=Availability; 3=Cheap to buy; 4=Less cost of hiring labour; 5=More market access; 6=Increases shelf life; 7=More yield; 8=More marketable produce; 9=Easy maintenance; 10=Easy to use; 11=Better market prices; 12= others (specify)*.......................

1.2.8. If have **not adopted *give the most important*** .reason...................... **(Code F)**

> ***Code F:** 1=high cost of acquiring 2= not available 3= lack of training4=cannot be used for other enterprises 5=high labour requirement 6= not easy to use 7= high cost of maintenance 8= lack of water, 9= lack of electricity 10= lacked money 11= the practice does not help me reduce post harvest losses, 12= am not involved in harvesting, 13= poor prices, 14= lack of market, 15= others(specify)*................

1.2.9. Would you like to use any of the practices in the future? [___] 1=Yes; 0=No

1.3.0: If yes give a recommendation that you would like done to facilitate your adoption……………………

SECTION 2:WILLINGNESS TO PAY FOR THE POSTHARVEST STORAGE AND VALUE ADDITION TECHNOLOGIES (PSVAT) (POTENTIAL ADOPTION)

2.1 TRAINING ON POSTHARVEST STORAGE AND VALUE ADDITION TECHNOLOGIES

2.1.1 Have you been trained on postharvest storage and value addition technologies through the UON postharvest project? [___] 1=Yes; 0=No

(If No in 2.1.1 above, before asking the following questions, the enumerator should explain to the farmer about the PSVATs and how they work to reduce postharvest losses.)

The University of Nairobi and partners have upgrade two fruit aggregation centers by providing proven postharvest technologies such as solar tunnel dryer, brick coolers and charcoal cold storage technologies (show photos). The project has also provided processing equipment within the aggregation centres in order to attain innovative wet, dry and dehydrated products. Farmers have the option of selling their fruits to the aggregation centres and/or purchasing PSVATs of their choice. The expected benefits include reduced postharvest losses, increased shelf life of the fruits, extended marketing period and higher profitability.



2.2 WILLINGNESS TO SELL FRUITS TO THE AGGREGATION CENTER

2.2.1. Would you be willing to sell your mangoes to the aggregation center in future? 1= Yes /___/ 0= No /___/

If NO, give the most important reason (Code F)…………………………………..

2.2.2. If Yes in 2.2.1 above, would you be willing to sell to the aggregation center at KES. 6 per mango piece? ? 1= Yes /___/ 0= No /___/

2.2.3. If for the bid in 2.2.2 is NO, increase the KES. 6 bid by KES. 1 until you reach the highest bid he/she is willing to sell. Record this highest bid………………..

2.2.4 If yes in 2.2.2 fill the table below indicating maximum mango pieces you or this household would be willing to sell to the aggregation center in the next ten years

Year	No. of mango pieces	Year	No. of mango pieces	Year	No. of mango pieces	Year	No. of mango pieces	Year	No. of mango pieces
2019		**2020**		**2021**		**2022**		**2023**	
2024		**2025**		**2026**		**2027**		**2028**	

2.3 WILLINGNESS TO PAY FOR CHARCOAL COOLER

2.3.1. Would you be willing to construct a charcoal cooler in future? 1= Yes /___/ 0= No /___/

If NO, give the most important reason (Code F)…………………………………..

2.3.2 If Yes in 2.3.1 above, would you be willing to pay KES. 10,000 to construct 1M^3 of charcoal cooler with a capacity of 163 mango pieces? 1= Yes /___/ 0= No /___/

2.3.3. If for the bid in 2.3.2 is YES, increase the KES. 10, 000 bid by KES. 2,000 until you reach the highest bid he/she is willing to pay. Record this highest bid………………..

2.3.4. If for the bid in 2.3.2 is NO, decrease the KES. 10,000 bid by KES. 2,000 until you reach the lowest bid he/she is willing to pay. Record this bid………………..

2.3.5. If yes in 2.3.2, fill the table below indicating maximum mango pieces you or this household would be willing to store in the charcoal cooler in the next ten years

Year	No. of mango pieces	Year	No. of mango pieces	Year	No. of mango pieces	Year	No. of mango pieces	Year	No. of mango pieces
2019		**2020**		**2021**		**2022**		**2023**	
2024		**2025**		**2026**		**2027**		**2028**	

2.4 WILLINGNESS TO PAY FOR ZERO ENERGY BRICK COOLER

2.4.1 Would you be willing to construct a zero energy brick cooler in future? 1= Yes /___/ 0= No /___/

If NO, give the most important reason (Code F)…………………………………..

2.4.2. If Yes in 2.4.1 above, would you be willing to pay KES. 20, 000 to construct 1M^3 of brick cooler with a capacity of 150 mango pieces ? 1= Yes /___/ 0= No /___/

2.4.3 If for the bid in 2.4.2 is YES, increase the KES. 20, 000 bid by KES. 5,000 until you reach the highest bid he/she is willing to pay. Record this highest bid………………..

2.4.4 If for the bid in 2.4.2 is NO, decrease the KES. 20,000 bid by KES. 5,000 until you reach the lowest bid he/she is willing to pay. Record this bid………………..

2.4.5 If yes in 2.4.2 fill the table below indicating maximum mango pieces you or this household would be willing to store in the brick cooler in the next ten years

Year	No. of mango pieces	Year	No. of mango pieces	Year	No. of mango pieces	Year	No. of mango pieces	Year	No. of mango pieces
2019		**2020**		**2021**		**2022**		**2023**	
2024		**2025**		**2026**		**2027**		**2028**	

2.5 WILLINGNESS TO PAY FOR TUNNEL SOLAR DRYER

2.5.1 Would you be willing to construct a tunnel solar dryer in future? 1= Yes /___/ 0= No /___/

If NO, give the most important reason (Code F)…………………………………..

2.5.2. If Yes in 2.5.1 above, would you be willing to pay KES. 25,000 for 1M^3 of tunnel solar dryer with a drying capacity of 40 mango pieces? 1= Yes /___/ 0= No /___/

2.5.3. If for the bid in 2.5.2 is YES, increase the KES. 25,000 bid by KES. 5,000 until you reach the highest bid he/she is willing to pay. Record this highest bid………………..

2.5.4. If for the bid in 2.5.2 is NO, decrease the KES. 25,000 bid by KES. 5,000 until you reach the lowest bid he/she is willing to pay. Record this bid………………..

2.5.5 If yes in 2.5.2, fill the table below indicating maximum mango pieces you or this household would be willing to dry using the tunnel solar dryer in the next ten years

Year	No. of mango pieces	Year	No. of mango pieces	Year	No. of mango pieces	Year	No. of mango pieces	Year	No. of mango pieces
2019		**2020**		**2021**		**2022**		**2023**	
2024		**2025**		**2026**		**2027**		**2028**	

SECTION 3: ACCESS TO CREDIT/FINANCING

3.1 Did any member of the household obtain agricultural credit in the last 12 months? [____] 1= Yes 0=No

3.1.1. If yes, provide the following details

Household member who accessed credit (Code G)	Main Source of agricultural loan (Code *H*)	Distance to the nearest credit provider (Km)	Amount borrowed (KES)	Interest rate for loan (%)	Satisfaction with credit services *(Code I)*	Purpose of the loan (*Code J*)

Code G: 1= *household head 2= spouse 3= children 4= relative 5=others (specify)* **CODE H: Source of Loan** 1. Micro-finance institution (SACCO) 2. Commercial banks 3. Cooperatives 4. NGOs 5. Government credit schemes (Youth Enterprise Fund, Women Enterprise Fund, Constituency Development Fund, Poverty Eradication Fund, Disability Fund) 6. Agricultural Finance Corporation 7. Local money lender 8. Group/Table banking 9. Family and friends 10. Contractual out grower arrangements	**CODE I: Satisfaction level** 1=Very dissatisfied 2=Dissatisfied 3=Neutral 4=Satisfied 5=Very Satisfied	**CODE J: Purpose of the loan** 1. Purchase farm inputs for mango production (e.g. seeds, fertilizers e.t.c.) 2. Purchase farm inputs for other enterprises 3. Buy livestock **4.** For marketing and value addition activities 5. Buy land 6. Construction of farm structures 7. Buy machinery and equipment 8. Payment of labor costs 9. Irrigation facilities

SECTION 4: GROUP MEMBERSHIP

4.1. Did any member of this household belong to an agricultural group/association during the last one year? [__ __] (1 = Yes, 0 = No)

If yes, provide the following information for the three main groups

	Who in your household is a member of an agricultural group (CODE G)	**Type of group** ***(See 0 below)***	**What main commodity does the group deal in? (*See* *Error! Reference source not found.* *below)***	**Purpose of group (*See* *Error! Reference source not found.* *below*)**	**Leadership position (*See* *Error! Reference source not found.* *below*)**	**Is the group registered? (*1=Yes ; 0= No*)**
1	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
2	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
3	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]

CODE K: (TYPE OF GROUP)	**CODE L: COMMODITY FOR GROUP**	**CODE M: PURPOSE OF GROUP**		**CODE N: LEADERSHIP POSITION**
1. Producer 2. Cooperative/ Society 3. Marketing 4. Producer and Marketing 5. Processing 6. Water users associations 7. Labour groups 8. Environmental management group 9. Nutrition support groups 10. Credit	1. Mangoes 2. Other crops 3. Livestock 4. Tree nurseries Other (specify) -----	1. Produce marketing 2. Input access/marketing 3. Seed production 4. Farmer research group 5. Savings and credit 6. Tree planting and nurseries 7. Soil & water conservation	8. Input credit 9. Water resource management 10. Communal labor provision 11. Environmental management e.g. conflict management, grazing land management 12. Utilization of farm produce 13. Processing	1. Chairman 2. Secretary 3. Treasurer 4. Member 5. Other

SECTION 5: EXTENSION SERVICES AND TRAINING

5.1. In the last one year, has the household received any form of agricultural extension service/training on farming? [___] 1=Yes; 0=No

5.1.1. If yes, complete the table below.

Household member who received extension/training Code: G	Source of extension/Training (Code O)	Frequency of visits/training (Code P)	Had you requested for the service (1= Yes; 0= No)	Level of satisfaction (Code Q)	Distance to extension office (Kms)	Enterprise (Code R)	Subjects covered (Code S)

Code G: 1= *household head 2= spouse 3= children 4= relative 5=others (specify)*

Code O: 1=Government, 2=Private, 3=NGO, 4=CBO, 5= other farmers, 6= other (specify)

Code P: 1=Never; 2=fortnightly; 3=Monthly; 4=quarterly; 5=annually

Code Q: 1=Very Dissatisfied; 2=Dissatisfied; 3=Neutral; 4=Satisfied; 5=Very Satisfied

Code R: 1= Mango production; 2= Livestock production; 3= crop production

Code S: 1=Good agronomic practices; 2=post-harvest handling (specify)……………; 3=farming as a business (specify)…………….

SECTION 6: ACCESS TO INPUTS

6.1 Kindly give us information on the use of inputs for mango production.

Activities		Unit	Quantity	Price	Activities		Unit	Quantity	Price
1	trees	NO.			*13*	Pruning	Man-days		
2	Quantity harvested	pieces			*14*	Desuckering	Man-days		
3	Home Consumption	pieces			*15*	Thinning	Man-days		
4	Qty given as gift	pieces			*16*	Top dressing	Man-days		
5	Qty Wasted	pieces			*17*	Harvesting	Man-days		
6	Qty Freshly sold	pieces			*18*	Grading	Man-days		
7	Qty processed	pieces			*19*	Transporting	Days		
8	Manure	Kgs			*21*	Storage	Days		
9	Chemical fertilizer	Kgs			*22*	Machine rental	Days		
10	Pesticide 1	Kgs			*23*	Other inputs	KSH		
11	Pesticide 2	Kgs							

6.2. Do you have any constraints to input access? [___] 1=Yes; 0=No.

6.2.1 If yes, what are the constraints? *(Tick appropriately)*

*(**Code T**: 1=none; 2= High prices; 3= Distance to input market …………Kms…………. Walking hours; 4= Distance to water source…………Kms………….. Walking hours; 5 = Distance to aggregation centre…………Kms………….. Walking hours; 7= Poor quality of inputs; 8= Lack of access too input at the right time; 9= others (Specify)……………)*

SECTION 7: MARKET INFORMATION AND ACCESS

7.1 Do you have access to produce markets? [___] 1=Yes; 0=No.

7.2 What is the distance to the nearest main market Centre from the farm? (Kms)___________

7.3. What is the type of road from the farm to that main market? [___] *(**Codes U**: 1=Tarmac, 2=All-weather marram road, 3=Seasonal marram road, 4=other (specify)*

7.4 Which products do you sell? [___] (**Code V**: 1=Mango 2 = Bananas 3 =Pawpaw 4= Passion 5= Avocado 6= Watermelon 7=Tomatoes 8=Butternut 9=Others (specify………….)

7.5. Are there any challenges in accessing market for your mangoes? [___] 1=Yes; 0=No.

7.5.1. If yes, specify using the codes below: ***CODE W****: 1= poor road network 2= distance to the markets 3= poor market prices 4= lack of contracts and reliable buyers 5= exploitative middlemen 6= lack of contact with buyers before harvest 7=others (specify) ………………*

7.6. Before harvesting do you seek information on market prices for your mango products? [___] 1=Yes; 0=No

7.6.1. If yes, what are the most important sources of market price information? [___] *(**Codes X**: 1=mass media, 2=government agricultural marketing information centres, 3=traders; 4=internet, 5=extension officer, 6=contract company, 7=cooperatives, 8=mobile phone services, 9=others)*

7.7. Marketing costs in last transaction of Mango by farmer

1. How much qty did you sell?	Qty			
2. Cost items for this transaction		Did you pay?	If yes, how much?	
		1. Yes 0. No	KSH	Unit code *1. Kg 2. Bag* *3. Full consignment*
a. Bagging (+stitching) or boxing				
b. Transportation				
c. Loading				

d. Off-Loading				
e. Payments at checkpoint or road-block				
f. Personal transport to wholesale market and/or back				
g. Entry license fee at the market				
h. Weighing fees				
i. Grading				
j. Storage				
k. Other expenses:__________				
8. How much quantity was wasted because of sampling and transacting (kgs)	Kgs			
9. Did you have to incur a "loss" discount (example deliver 83.7 kgs and paid for 80 kgs)?	KSH			
10. Advance received?	*1. Yes 2. No*			
11. Total amount received for the transaction (including advance)?	KSH			

SECTION 8. MANGO POSTHARVEST HANDLING INFORMATION

		Cost
8.1. How is your crop handled immediately after harvest?	1. On ground in sun	
	2. On ground in shade	
	3. In basket	
	4. In crate	
	5. In cart	
	6. In plastic bag	
	7. In plastic sack	
	9. Other (Specify)	

8.2. Do you precool your produce? 1=Yes 0=No	
	Cost

8.3. If YES, how do you precool?	1. Place in shade	
	2. Sprinkle water over crop	
	3. Cover with leaves/palms	
	4. Place in cold room	
	5. Use umbrella, shadehouse	
	6. Other (Specify)	

		Cost
8.4. How is your produce brought from the field to the homestead? **(*Tick only one.*)**	1. Baskets on foot	
	2. Bicycle	
	3. Hand cart/push truck	
	4. Motor bike	
	5. Pick-up truck	
	6. Motorized tricycle	
	7.Crates	
	8.Other (Specify)	
	8. Not applicable	
8.5. What is the type of packaging you use to transport produce to the market? **(*Tick only one?*)**	1. Plastic Bag	
	2. Sacks (Woven Polypropylene)	
	3. Baskets	
	4. Wooden boxes	
	5. Large crates	
	6. Paper boxes/Cartons	
	7. Insulated/Styrofoam boxes	
	8. Loose	
	9. Other (Specify)	

8.6. What value addition activities do you do for mangoes? ***(Tick all that applies.)***	1. Grading	
	2. Sorting	
	3. Cleaning	
	4. Packing	
	5. Labeling	
	6. Cooling	
	7. Storage	
	8. Transportation	
	9. Processing (Juicing, canning, drying, etc)	

SECTION 9: MARKET STRUCTURE AND CONDUCT

9.1. During the past 3-5 years who have been the main buyers of your mango fruits and mango products and what % of the total produce do they buy on average (*In case you sell to more than one customer or group of customers, give in a rank of 1st to 6th in front of the list below*)

Buyer	Percentage of the products bought	Rank by the frequency and majority of your transaction	Price per Kg or piece of mango
Retailer (local)			
Retailer (Non-local)			
Broker/Middle men			
Processor			
Wholesaler			
Exporter			

9.2. Do you sell to the same buyer(s) each time? Tick your choice. YES =1 NO=0

9.2.1. If your answer is **<u>YES</u>** to question number **14.2**, why? Tick X in front of your choice for the following list of reasons.

I have written contract with the buyer(s)	
I am going to get benefit from the profit of the buyer- case of member farmer in cooperatives	
I have strong/ trust based/ business relationship with the buyer	
I have no other optional buyer(s) in my area	

9.2.2. If your answer is **NO** to question number **14.2** why? Tick X in front of your choice.

Because I am selling by selecting the best offer price every time	
Because different buyers approach me at different time; I don't have permanent customers	
Other reason, specify………………………………………	

9.3 Are there challenges associated with contracts? 1= Yes 0=No

9.4 What are the losses when contracts break?...

9.5. How do you decide to whom to sell your fruits and/or processed product? Give rank from 1 to 4 based on your priority of criteria of decision.

Criteria of Decision	**Rank by priority**
By selecting the best price	
Based on the business relationship	
Based on the ownership in the cooperatives	
Based on the delivery convenience; I prefer buyers who come near to my farm	
I accept the price offered by the buyer	
Other (specify)	

9.6. When do you receive payment for your fruit product **often**? Tick **X** in front of your choice.

Immediately after sale	
Within a week time after sale	
Two to three weeks' time after sale	
Within a month time after sale	
More than a month time after sale	

9.7. Do you regularly seek out quantity information before procuring the commodities? [___] 1 = Yes; 0 = No

9.8. What is the **major** factor that limits traders' ability to engage in mango product(s) trade?...........

1=poor road infrastructure
2=Inadequate storage capacity
3=lack of appropriate storage facility
4=inadequate start-up capital
5=poor access to credit
6=price instability
7=low trade margin
8=lack of standard measures
9= Perishability
10 =poor access to transportation means
11= Bulkiness
12 = lack of market information
13= long distance movement between supply and resale markets
14. Others (Specify)…………………………………………………………

SECTION 10: SOURCES AND LEVELS OF HOUSEHOLD INCOME

10.1. INCOME FROM OFF-FARM AND NON-FARM ACTIVITIES

	Off-Farm income activity – define off-farm- not related to your farm	**Did someone in your household receive income from that activity? (1=YES; 0= NO)**	**If YES, who generally receives that income? (See 0 below)**	**Amount received in the last 12 months (KES)**
1	Salaried employment (household head)	[______]	[______]	[______________]
2	Salaried employment (spouse)	[______]	[______]	[______________]
3	Pension Income	[______]	[______]	[______________]
4	Social protection	[______]	[______]	[______________]
5	Farm labour wages (household head and spouse)	[______]	[______]	[______________]
6	Non-farm labour wages (household head and spouse)	[______]	[______]	[______________]
7	NET income from business (e.g. posho milling, trading, shops, tailor, charcoal, crafts)	[______]	[______]	[______________]
8	Amount received from children within household (employment or off-farm income)	[______]	[______]	[______________]
9	Remittances (from relatives from outside household)	[______]	[______]	[______________]
10	Renting out land	[______]	[______]	[______________]
11	Renting out equipment/machinery	[______]	[______]	[______________]

CODE Y:(WHO GENERALLY RECEIVES INCOME)

	Off-Farm income activity – define off-farm- not related to your farm	Did someone in your household receive income from that activity? (1=YES; 0= NO)	If YES, who generally receives that income? (See 0 below)	Amount received in the last 12 months (KES)

1. Head of household (HHH) 2. Spouse of household head 3. Joint HHH and spouse	4. Male household relative 5. Female household relative 6. Non-relative household member (male)	7. Non-relative household member (female) 8. Children

10.2 FARM INCOME

	Income from farm related activities (in the last 12 months)	Did someone in your household receive income from that activity? (1=Yes; 0= No)	Who mainly receives that income? (See Error! Reference source not found. above)	Amount received in the last 12 months (KES)
1	Income from crop activities (include agroforestry)	[______]	[______]	[__________________]
2	Income from livestock activities (including beekeeping, use of bulls for AI e.t.c.)	[______]	[______]	[__________________]
3	Income from woodlot activities (farm forest)	[______]	[______]	[__________________]
4	Income from fishing activities (pond and natural)	[______]	[______]	[__________________]
5	Income from renting out/selling pastures and forages	[______]	[______]	[__________________]
6	Any other farm income	[______]	[______]	[__________________]

10.3. How many parcels of land are <u>owned</u> and/or <u>accessed</u> by the household? ____________________

10.4. What is the total size of all the land OWNED (in acres)? ____________________ acres

10.5.Do you have title to your land? [___] 1=Yes; 0=No

10.6.How was the land allocated to the different uses in the last 12 months (*specify area in **acres***)?

*Homestead …… Subsistence crops production ……. Commercial crops production ……. Mangoes ……. Livestock/Fodder …… Unusable land (swampy, rocky, hilly) ……… Woodlot ………*rented out (in acres)?..................................

SECTION 11: HOUSEHOLD DETAILS:

Members of The Family (name)	Sex of Person (1=Male; 2=Female)	Relationship to household head (**code G)**	Number of years of schooling	Primary occupation (**code Z**)	Marital status (**code AA**)	Year of birth
(respondent)						

Code G: *1= household head* *2= spouse* *3= children* *4= relative* *5=others (specify)*	***Code Z:*** *1=crop farming* *2=Livestock keeping* *3= Mixed farming* *4= Formal salaried employment* *5= Self-employed business*	*6= Old/Retired /Pensioner* *7= Remittances* *8= Student/ pupil* *9= Farm worker* *10=others (specify)*	***Code AA:*** *1= single 2= married 3= separated 4= widow/widower 5=none*

Thank you for your cooperation.

APPENDIX 2: EXPERT OPINION SURVEY QUESTIONNAIRE

POTENTIAL ECONOMIC IMPACT OF POSTHARVEST TECHNOLOGIES ALONG THE MANGO VALUE CHAIN IN KENYA

INTRODUCTION TO THE RESPONDENT

Hello, my name is Esther Achieng' and I am part of the research team from the University of Nairobi required to evaluate the potential economic impact of some postharvest technologies along the mango value chain. This is in partial fulfillment of my PhD degree at the University of Nairobi. Note that the information offered herein shall be confidential and crucial in employing the economic surplus model.

Name of Respondent (Optional): ....

Date: ....

Institution:...

Contact:...

1. Are you aware of postharvest technologies along the mango value chain?

   1 = Yes □ 0 = No □

2. If yes, which of the following are you aware of and how would their adoption in Kenya affect mango yield?

Component	**Aware (1=Yes, 0=No)**	**Yield change (%)**
Evaporative charcoal cooler		
Zero energy brick cooler		
Tunnel solar dryer		

3. How many years do you think it would take farmers to adopt this technology?........................

4. What would be the adoption level of the above technology?.................................%.

5. For how many years would the famers adopt the technology?................................

6. What would be the rate of annual depreciation of the technology (expected annual reduction in yield).......................%

Thank you!

APPENDIX 3: CONSUMER SURVEY QUESTIONNAIRE

CONSUMER AWARENESS AND WILLINGNESS TO PAY FOR NATURALLY PRESERVED MANGO PRODUCTS

INTRODUCTION

This survey is being conducted by researchers from the University of Nairobi. The purpose of the survey is to understand consumer awareness and willingness to pay for naturally preserved mango products. Your responses and opinion will be treated with utmost confidentiality and will only be used for research purposes.

IDENTIFICATION

Interviewer's name1= Charles Maina 2= Winston Mbogo 3 = Cynthia Ogada 4= John Kinyua 5= Herman Njuguna 6= Stanley Makumi 7= Dorcas soyian 8= Isabela Muthoni Date of interview...................................

Place of interview: 1= Zuccchini 2= Chandarana 3= Carrefour 4= Tuskys 5= Naivas 6= Eastleigh

Section 1: Awareness and consumption patterns of mango products

1. Which mango products are you aware of? 1= Mango juice 2= Mango juice blends 3= Mango chips/crisps 4= Mango leather 5= Mango pulp 6= Mango Jam
2. How often do you purchase the following mango products? (Tick appropriately)

	Never	**Daily**	**Weekly**	**Fortnightly**	**Monthly**	**Other(Specify)**
Mango juice						
Mango juice blends (Specify)Mango………..………						
Mango chips/crisps						
Mango leather						
Mango pulp						
Mango Jam						
Other (Specify)						

3. What quantities do you usually purchase?

	100gms	250ml	500ml	1Litre	5 Litres	Other(Specify)
Mango juice						
Mango juice blends						

Mango chips/crisps						
Mango leather						
Mango pulp						
Mango jam						
Other (Specify)						

4. Which brand of processed mango products do you prefer the **most** and **why?** ***Brand***
(1= Del Monte 2= Kevian (Pick N peel, Afia range, Mt. Kenya) 3=Azuri Health
4= Excel Chemicals 5= Coca Cola 6=Other..**)**
Reason..
5. Where does your household purchase mango and mango products 1= Supermarket 2= Retail store 3= Kiosk/open-air market 4= Other (specify)
b) How frequently does your household purchase from the following outlets?

		Never	**Rarely**	**Sometimes**	**Often**	**Always**
i)	Supermarket					
ii)	Retail store					
iii)	Kiosk/open-air market					
iv)	Other (specify)					

6. Which of the following factors influence your purchasing decisions on mango and mango products? 1= Nutritional information 2= Price 3= Taste or flavour & Colour 4= Brand name/source 5= Advertisement 6= Packaging 7= Circle of friends
b) How important are the following factors in influencing your purchasing decisions on mango products?

		1. Not at all important	**2. Somewhat Important**	**3. Moderately Important**	**4. Fairly Important**	**5. Very Important**
i	Nutritional information					
ii	Price					
iii	Taste or flavour & Colour					

iv	Brand name/source?					
v	Advertisement					
vi	Packaging					
vii	Circle of friends					

7. Do you normally seek prior information **regarding the aspects above**, before making food purchasing decisions? [1= Yes, 0= No]………………

8. If yes to Q 7, Which of the following sources do you get information about food and nutrition ? 1= Food advertisements (Billboards,Posters) 2= Media (Radio, T.V, Newspaper, etc) 3= Public seminars 4= Family and Friends 5= Healthcare professionals 6= Other, please specify………………………….

How frequently (daily, weekly, monthly, annually, biannually)?

	Source	**Yes/No**	**Frequency**
i	Food advertisements (Billboards,Posters)		
ii	Media (Radio, T.V, Newspaper, etc)		
iii	Public seminars		
iv	Family and Friends		
v	Healthcare professionals		
vi	Other, please specify		

9. How often do you normally read labels when you purchase mango products?

Never	**Rarely**	**Occasionally**	**Often**	**Nearly Always**

Section 2: Consumer perception and awareness of preservatives

10. Are you aware of the preservatives used in your preferred products? [1 = Yes, 0 = No]
11. Which preservatives are you familiar with a) Citric Acid b) Sodium Metabisulphite c) Others
12. Do you think these are good for your health? [1 = Yes, 0 = No]
13. If no, why

Section 3: Consumer willingness to pay for naturally preserved mango processed products

14. What is the price of the mango products that you purchase?

	100gms	250ml	500ml	1Litre	5 Litres	Other(Specify)

Mango juice						
Mango juice blends						
Mango crisps						
Mango chips						
Mango leather						
Mango pulp						
Other (Specify)						

15. Would you be willing to pay more for naturally preserved mango processed products?
[1 = Yes, 0 = No]
16. If yes, how much more would you be willing to pay for each naturally preserved mango product?

	100gms	250ml	500ml	1Litre	5 Litres	Other(Specify)
Mango juice						
Mango juice blends						
Mango crisps						
Mango chips						
Mango leather						
Mango pulp						
Other (Specify)						

Section 4: Consumer characteristics and demographics

17. Indicate how the statements below best describe you and your household;

	1. Never	**2. Rarely**	**3. Not sure**	**4. Often**	**5. Always**
Read newspaper/magazine articles on food safety					
Listen to radio discussion programmes about food safety					
Watch television/cable programmes on food safety					

18. Marital status of the respondent: [1= Single, 0= Married]
19. Please indicate your occupation .... 0= None 1= Formal salaried employment 2= Self-employed business 3= Casual labourer 4= Retired /Pensioner 5= Farmer 6= Student/ pupil 7= Other
20. Gender of the respondent: [1= Female, 0= Male]
21. Region from which the respondent resides: [1= Rural, 0= Urban]
22. Please indicate your highest level of formal education attained in years……………..
23. Please indicate your age in years ……………………..

Thank you for your participation