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Assessment of the Use and Barriers of Evaporative Cooling Technologies by Small Holder Farmers in Kenya

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EXECUTIVE SUMMARY

The project report addresses the awareness, use, and barriers to adoption of Evaporative Cooling Technologies (ECTs) in the Embu and Machakos Counties of Kenya. The goal of this project was to identify the level of awareness that farmers have of evaporative cooling technologies, barriers to adoption, and ultimately, to generate design and dissemination recommendations, which will improve the user experience. Providing a cool and humid storage environment for harvested produce is key to increasing produce shelf life. Conventional cooling options, such as the use of a refrigerator, have shown to be effective, however, these technologies may be out of reach for most smallholder farmers due to the high cost and need for electricity. This situation calls for development and dissemination of alternative postharvest storage options. Evaporative Cooling Technologies (ECTs), such as a charcoal and brick cooling chambers or Zeer-pots, have been shown to be affordable to construct and operate; however, adoption of these technologies has not been widespread. This study sought to determine both the reasons for use and factors which hinder adoption of ECTs. Data were collected through a structured questionnaire administered to 81 mango farmers in two contrasting agroecological zones. Data were analyzed to determine the correlation between demographics and farmers' knowledge and awareness of postharvest cooling technologies. The findings reveal that most (58) farmers are aware of at least one type of cooling chamber and most of those who use either a brick cooler or charcoal cooler belong to a cooperative farming group, indicating the strength of cooperative movements. The respondent's education level and access to training and extension services influenced use of cooling storage, indicating the need for education of benefits for the use of cooling storage. The widespread adoption of cooling technologies would help reduce food losses all along the value chain, contributing to the achievement of the United Nations Sustainable Development Goal #2: Zero Hunger.

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1.0 Introduction

1.1 Significance of agriculture in Kenya

The agricultural sector is key to Kenya's economic development, accounting for 28% of the Gross Domestic Product (GDP) and 27% (indirectly) through linkages with agro-based industries [25, 3]. The horticulture sub-sector contributes 33% of the agricultural GDP and employs over six million people annually. In recent years, there has been increased production of fruits and vegetables driven by consumer awareness of the health and nutritional benefits accompanied by high postharvest losses.

1.2 Mango production and postharvest challenges

In the last decade, mango production in Kenya expanded considerably in acreage and geographical spread. The growth of the industry has been stimulated by a continuous increase in demand in the domestic, regional and international markets [3], becoming a major income earner for many smallholder farmers living in dry areas (Arid and Semi-Arid lands). Although mango fruit is highly perishable with a short shelf life of 4 to 5 days under ambient room temperature (25 °C), cold storage at 13°C can increase the shelf life of mangoes to 3 weeks [8]. Studies have shown that 40-50% of fruit crops such as mango is lost before it can be consumed [1]. As a climacteric fruit, mango has a short shelf life that is highly dependent on harvest maturity and storage conditions [26]. Its perishability and seasonality are the main causes of the postharvest losses experienced along the value chain.

1.3 Cooling technologies

Insufficient cold chain management, which entails handling and storage of perishable produce at safe (low) temperatures, contributes significantly to the postharvest losses. In addition to fresh commodities spoilage, the lack of effective and affordable storage options often requires farmers to travel every day to sell their products at the market, resulting in lost time and money. Conventional cold rooms are not only unaffordable for typical smallholder farmers, but also impractical due to lack of electricity in most rural areas. ECTs hold great promise to address cold chain challenges among smallholder farmers and traders. ECTs function through direct evaporative cooling: heat is removed as water evaporates from the surface of the storage device, decreasing temperature (up to 15 °C below ambient temperatures) and increasing in moisture content of the air (up to 100% relative humidity), conditions that substantially improve vegetable shelf life, increase the marketing period, reduce food loss, and ultimately increase income for farmers. Despite the benefits, adoption of ECTs in Kenya is very low despite the potential benefits. This study looks to generate evidence of some of the reasons for use and factors hindering adoption of ECTs in Embu and Machakos Counties in Kenya.

1.4 Technology adoption

The decision to adopt a technology is usually an investment decision, presenting a farmer or farming group with a shift in investment options [34]. The cost of the technology and whether the farmers have the resources to acquire the technology can play a large role in determining if such an investment can be made. Lack of capital to invest in technologies can be dealt with increasing credit availability and education on the availability of such. Some technologies remain unadopted due to perceived high cost of acquisition, which is not always the case. Agricultural training and extension programs can be effective in promoting adoption of technologies [35]. Training of the extension workers on new technologies can avoid the dissemination of information that has become technologically obsolete. Participating in farming groups has been shown to be helpful as participants get important information in production, postharvest handling and marketing [31]. Other benefits for farmers belonging to a cooperative farming groups include exposure to agricultural best practices, bulk purchasing and better prices for inputs, and improved negotiating strength with buyers [30]. Synergy creation between government and non-government organizations, research, donors and local communities can also be created. Knowledge about a technology demystifies perceptions and reduces the uncertainty about a technology's performance and can better inform the decisions on technology adoption [34].

1.4 Research objectives

1. To assess farmer awareness and use of the different evaporative cooling technologies in Embu and Machakos.
2. To determine barriers in the adoption of evaporative cooling technologies for these farmers.

2.0 Background

2.1 Mango production in Kenya

Mango (*Mangifera indica* L.) is an exotic tree in Kenya that has been grown along the Kenyan Coast for centuries. It is said to have originated from India, Myanmar, Malaysia and Bangladesh, and is now grown in over 90 countries worldwide [2]. The mango tree is thought to have been introduced by slave traders during the 14th century who brought the seeds with them. Mango production in Kenya includes both small- and large-scale holders for both the domestic and export market. The main varieties grown include Sabine, Ngowe, Tommy Atkins, Dodo, Van Dyke, Boribo, Apple, Kent and Haden. Generally, mango trees flower between July and November, depending on weather conditions. The varying ecological conditions in Kenya, allows for almost an all-year availability of mangos. In the coastal region, there are two supply seasons; the first and main season runs between November and February and the second between June and August. In higher altitude areas, the harvest season comes 4 – 6 weeks later than the coast, with a peak in February and March. In 2016, mango production volume decreased to 779,147 metric tons compared to 806,575 metric tons that was realized in 2015. The drop in production volume is attributed to the poor rains received in 2016 as mangos are mainly produced under rain-fed conditions [3]. Currently, mango is the leading export fruit crop from Kenya, comprising about 6% of the total export value of horticultural crops, however, its potential has not been fully unlocked. Export to Europe and to the East has been on the decline because of the production and postharvest challenges experienced including pests and diseases, unreliable supplies, climate change, harvesting at the wrong maturity level and poor postharvest technologies being the major constraints [4]. Various mechanisms have been exploited to curb the losses incurred, but most of them remain un-adopted because of price constraints especially to the poor resource farmers.

2.2 Challenges of mango farming in Kenya

2.2.1 Low prices and lack of market information

Many smallholder farmers depend on income from the sale of their fruits for their livelihoods. However, prices of mango fruits fluctuate from 0.05 to 0.25 USD per piece, limiting farmers from making projections and reliable planning from mango fruit income [5]. Often, farmers earn very low income from the sale of their mango fruits in spite of this fruit fetching very high prices at the final consumer [6]. Mango farmers that are not directly involved in the sale of mangoes and they are often manipulated by middlemen who end up with a disproportionate about of the profits along the supply chain. Furthermore, the limited access to information by mango farmers on technology in husbandry limits the potential of production, and when it comes to postharvest management they often lack access to or are unaware of technologies which could be used to increase the shelf life of their produce. This challenge is further compounded by the lack of information regarding existing methods of adding value to mangoes such as juicing and mango drying, which can fetch higher prices as well as reducing losses. Altogether, these challenges sometimes discourage farmers and can lead to them abandoning mango farming, thus affecting their economic status as well as that of their region.

2.2.2 Poor road network and lack of postharvest handling technologies

Poor infrastructure and postharvest handling in the major producing zones pose a great challenge to the mango farmers [7]. The roads in the rural areas are usually rendered impassable, especially during the wet season. And, even when the weather is dry, the roads are very bumpy, which hampers movement of produce. Poor produce packaging and lack of cold chain management causes the fruits to senesce fast contributing to huge losses. Few existing transportation technologies like CAs, MAPs and refrigerators, among others, are unaffordable or unknown to many farmers. Many times, the farmers use jute bags to pack the produce, however, these bags do not prevent fruits from physical damage and over packing leads to an increased respiration.

2.2.3 Lack of harvesting tools and techniques

The defects that arise right from harvesting, packing and transportation leads to postharvest decay [8]. More often, fruits are harvested and dropped on the ground, which causes skin injuries. During packing and sorting, fruits are roughly handled and thrown in bins or bags inducing bruises on the skin and removing cuticles. Friction damage is a serious problem during harvest and handling, and it has been estimated to occur in over 78% of the fruits. Damaged tissues become oxidized which later inclines downward and turn brown. The damaged surfaces lead to accelerated loss of water and causes disruption of the superficial arrangement of cells and tissues allowing a faster exchange of gas on the fruit surface. These sites also become entry points for disease causing microorganisms such as fungi and bacteria [8].

2.2.4 Lack of knowledge of optimal harvest time

Maturity is an important determinant of the mango eating quality. Changes in the parameters used to quantify maturity differs with region, variety and consumer perception. There are various ways of measuring maturity including chronological, physical, physiological and biochemical, each or a combination being suitable for a particular produce. When mangoes are harvested, it is important to differentiate between mature and immature fruits, since immature fruits never possess the full eating quality potential nor do they have the waxy layer that protects water loss which forms later as the fruit develops, leading to high water loss and a faster shrinking [9]. As the fruit mature, there is development of internal flesh color, which is an important indicator of maturity, as well as dry matter content which is correlated to the final total soluble solids attained by the fruit [10]. However, the fruit should not be harvested when they have started to ripen as this makes handling difficult. Further, respiration rates at this stage are higher, leading to high temperatures and thus faster deterioration of the fruits. Therefore, farmers and traders need to be educated to ensure they harvest only those fruits that are mature enough and which can withstand handling process during transport and marketing period.

2.3 Applicable Technologies for increasing shelf life and postharvest quality of Mango fruits

2.3.1 Cold storage

In developed countries, cold storage using conventional refrigerators is part and parcel of postharvest handling of fresh commodities. Low temperature is critical for lowering metabolic activity, reducing water loss, delaying ripening and senescence, disease and insect activity, all of which help maintain postharvest life and quality [11]. However, in less developed countries such as Kenya, where a majority of the farmers (80%) are smallholder farmers, the acquisition and operation of such technologies is limited due to capital outlay, operating costs, and lack of connection to the national grid in most rural areas. Developing and deploying of low-cost cold storage is necessary to boost farming in the rural areas where horticultural farming occurs. Evaporative Cooling Technologies (ECTs) are among the possible solutions that have the potential to provide value in this context.

2.3.2 Evaporative cooling technologies (ECTs)

Evaporative cooling chambers made from brick or charcoal both function on the principle of evaporative cooling. The coolers not only achieve low temperature surrounding the produce but also increases the air moisture content (relative humidity) which prevents drying of fresh commodities, thus increasing their shelf life [12]. The brick cooler is made up of a double wall filled with river sand in between, while the charcoal cooler is made by building a structure whose walls are filled with charcoal held up by wire netting [13]. The sand is wetted by a constant supply of water and as warm dry air passes through it, water evaporates taking with it heat from the environment within the storage chamber hence cooling the air around the product itself [14]. The main advantage of the evaporative cooling technologies is the fact that they can be made from locally available materials using unskilled labor making labor cost affordable, they do not require electricity for their operation and do not require significant training to operate, thereby making appropriate for smallholder farmers with limited resources. ECTs have been successfully used for storing spinach, potatoes, tomatoes, mangoes, bananas, among others, increasing shelf life by 3 to 15 days compared to produce stored in ambient conditions [16].

In the context of the present study, most of the farmers use ECTs for aggregating before selling to buyers, which reduces field heat and improves produce quality. Once the produce from fields arrives at the aggregation centers, it is sorted and stored in the chambers to remove field heat. If the field heat is not removed, it would result to overheating during transportation and storage resulting in increased water loss [33]. The ECTs employ the principle of evaporative cooling to maintain cool interior temperatures for produce preservation. The charcoal cooler is built from open timber frame with charcoal held in between wire mesh, while the brick cooler is built by having two walls of brick filled with sand. As the warm dry air passes through the moist medium (charcoal or sand), water is evaporated into the air resulting into a cooling effect. The charcoal and brick cooling chambers have benefits of increasing humidity and lowering the internal temperature hence increasing the shelf life of produce. Respondents in the current study indicated that they use the facilities for the benefit of increasing shelf life, providing them time to look for market resulting in better prices.

2.3.3 Controlled Atmosphere storage (CAs) and Modified Atmosphere Packaging (MAP)

The use of CAS and MAPS to delay ripening is achieved by reducing O_2 and increasing CO_2 levels thus reducing respiration rate and preventing water loss [17]. These systems also help to control insect and pathogen attack. CA is sophisticated and is used to achieve a constant temperature, oxygen and carbon dioxide. The high CO_2 levels achieved by CA can keep ethylene at low concentration since CO_2 antagonizes the 1-aminocyclopropane-1-Carbocylic Acid (ACC) synthase enzyme that converts S-adenosylmethionine (SAM) to ACC. Although CA storage has shown significant delay in the ripening process of mango, it is cost-prohibitive and typically only used for high value crops. There is also a tendency of CO_2 injury and formation of off-flavors due to anaerobic respiration [18]. On the other hand, MAP is the practice of modifying the composition of the internal atmosphere of a package in order to improve the shelf life of a commodity. Unlike in the case of controlled atmosphere storage, the gas composition in MAP is not precisely controlled and depends on the interplay between the commodities respiration and permeability characteristics of the package. MAP has been effective at the laboratory level and there are successful commercial applications that have been realized in fruits such as apples [19], loquats [20], and mangos [21], among others. However, mango has a short tolerance to elevated CO_2 and reduced O_2 which leads to off flavors and can cause non-uniform color development, making it an unfavorable option [22].

2.3.4 Waxing and Edible Coatings

Coating of fresh produce has been a practice of over centuries, mostly used to protect food and reduce moisture loss. Baldwin (1994) [23] reported that synthetic protection was first recorded in China where citrus fruits were coated with wax. Wax, oils or fatty acids of either animal or plant origin are usually applied on the surface of fruits or vegetables by brushing or spraying. The film is thinly applied to lower the rate of water loss and gas diffusion on the surface of fruits [23]. The film formed reduces the rate at which oxygen diffuses into the produce and this helps to lower the rate of respiration. The rate at which carbon dioxide resulting from respiration leaves the produce is lowered and this leads to buildup of Carbon dioxide in the fruit which helps to hinder the autocatalytic production of ethylene which causes fruit ripening [24].

3.0 Methodology

3.1 Sampling technique and data collection

The study was conducted in two counties, Embu and Machakos, in the East-African country of Kenya. Embu and Machakos counties are on different agro-ecological zones and both are known for mango production. The areas were purposively selected because of the large number of small-scale farmers who supply both the export and local markets. Data for this study were collected from a household survey that targeted mango producing farmers. A multistage sampling of 81 respondents was used with the help of the extension officers in the area. Fifty-nine farmers with at least one ECT and twenty-two without any ECT were identified in the two study areas and a semi-structured questionnaire was used to collect both quantitative and qualitative data. Data were collected on awareness and adoption of various ECTs, level of education, household head occupation, group membership, time to harvest, tools for harvest, access to extension services, training, land size ownership and losses experienced at different levels of production.

3.2 Data analysis

The data was analyzed using Statistical Product and Service Solutions (SPSS) version 20, by computing descriptive statistics including frequencies, percentages, means and averages.

4.0 Results and Discussion

4.1 Respondent Demographics

4.1.1 Region and gender

This study was carried out in two counties: Embu and Machakos, representing 52% and 48% of respondents; respectively. Table 1 presents a summary of the respondent demographics.

Table 1. Gender of the respondents in each county.

			Gender of the respondent		**Total**
			Female	Male	
County	Embu	Number of respondents	16	26	**42**
		% of Total	20%	32%	**52%**
	Machakos	Number of respondents	24	15	**39**
		% of Total	30%	18%	**48%**
Total		Number of respondents	**40**	**41**	**81**
		% of Total	**49%**	**51%**	**100%**

4.1.2 Occupation and education of the household head

In both regions of study, majority of the households' main occupation is farming (77%), and the least common occupation is salaried employment on-farm (Figure 1). Most of the workers on the farm are on casual basis and this explains the small proportion of those working on the farm based on monthly salary.

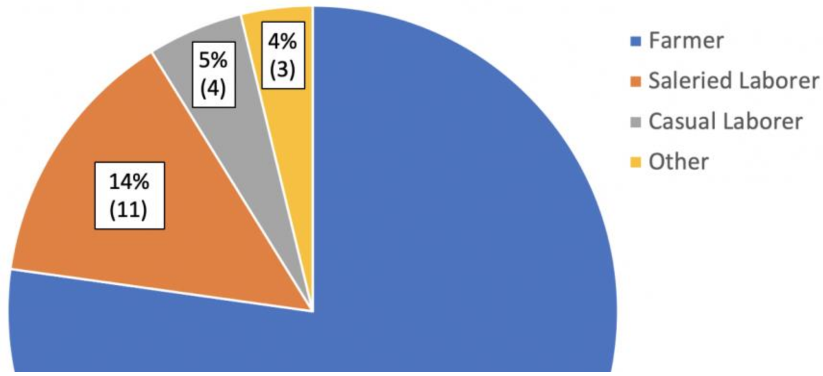

Figure 2 shows the education level of the household head, with 72% of the household heads having either primary or secondary education and 16% have received college training (tertiary education). The remainder have had no education or had informal education which includes adult education. The level of education is among the factors that were found to influence the decision-making process in the household including adoption of technologies such as the ECTs (see section "4.3 Factors influencing use and non-use behavior").

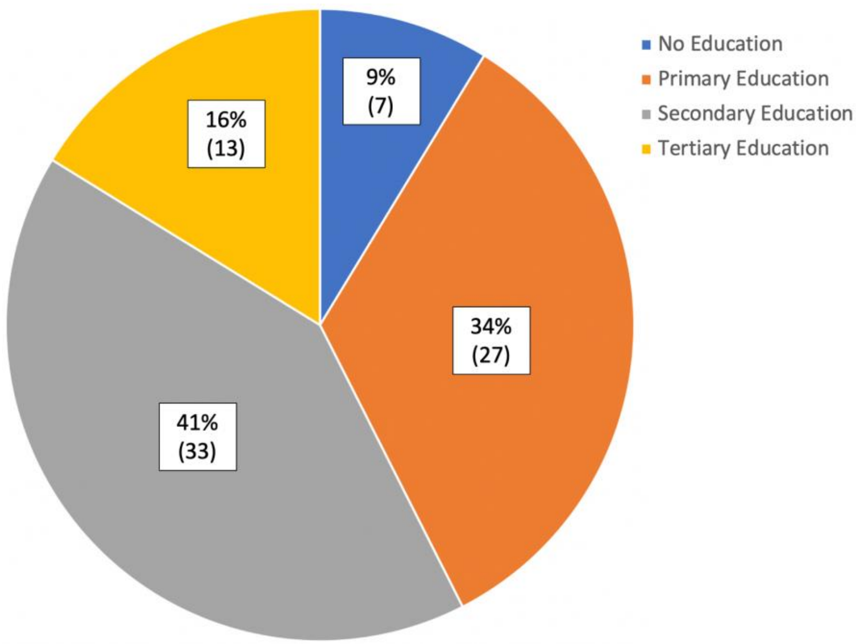

Figure 2. Levels of education of the household head *(the number of respondents is listed below the percentage).*

4.1.3 Land ownership

Land ownership and size has been shown to influence technology adoption [32]. In the current study, respondents owned small parcels of land and they did not have cooling technologies for personal use. Those who used the cooling technologies belonged to a cooperative farming group where they aggregated their produce for storage. The ownership of small pieces of land meant small volumes, which influenced decision on whether to store or sell directly. A majority of the respondents sold directly to traders whenever they came, and this influenced time for harvest. Changes that cost little are adopted quicker than those requiring large expenditures.

4.2 Farmer awareness and use of Evaporative Cooling Technologies (ECTs)

The knowledge and awareness of technologies is influenced by level (level of education) and the rate (trainings attended) of information sharing among other factors. This study found that the majority (73%) of the respondents had information about ECTs as compared to 27% of those who were not aware of ECTs. The awareness in Machakos (90%) was higher than Embu (57%). The contingency table (Table 2) summarizes the proportions of those with information and those without the information on ECTs as percentages within each county and percentages of the total sample size. The disproportion between those having information and those without information on ECTs is more in Machakos County, which had only 10% of respondents who had never heard about the ECTs, than in Embu County. Despite being aware of ECTs, 44% of those who have information about ECTs do not use them due to various reasons discussed later on.

Table 2. Differences in awareness of ECTs between the regions of study.

			Do you know of the Evaporative Cooling Technologies (ECTs)?		**Total**
			No	Yes	
County	Embu	Number of Respondents	18	24	**42**
		% within County	43%	57%	**100%**
	Machakos	Number of Respondents	4	35	**39**
		% within County	10%	90%	**100%**
Total		Number of Respondents	**22**	**59**	**81**
		% of Total	**27%**	**73%**	**100%**

4.2.1 Barriers to adoption of ECTs

Thirty seven percent (37%) of respondents who know about ECTs attributed the failure to use them with high costs of acquisition or lack of access to the technologies. From the study, all the ECTs used were group owned and were obtained or constructed with support from external bodies; Governmental and non-governmental. This explains why most users of ECTs in the regions belong to at least a cooperative farming group (see Table 3).

The most common reason cited for not adopting ECT technologies was the high cost of acquisition and maintenance. Some of the members of farming groups that owned at least one type of the ECTs estimated the cost of construction and maintenance of the chambers from Ksh 800,000 – 2,000,000 (approximately US $800 -$20,000), and these facilities were constructed by the help of external support.

Other barriers and challenges, illustrated in Figure 3, include the effectiveness and capacity of the chambers, as well as the cost of joining cooperative farming groups. Some users claimed that the chambers do not meet the expected performance therefore not making a significant enough improvement to shelf life of their fruits to justify their use. Some of the respondents who did not belong to a group were previously members but opted out due to the cost of retaining membership. Some farmers reported not using ECTs because they do not have large volumes of fruit or they sell their produce directly from their farm, both circumstances result in a situation where there is not a significant need for storage.

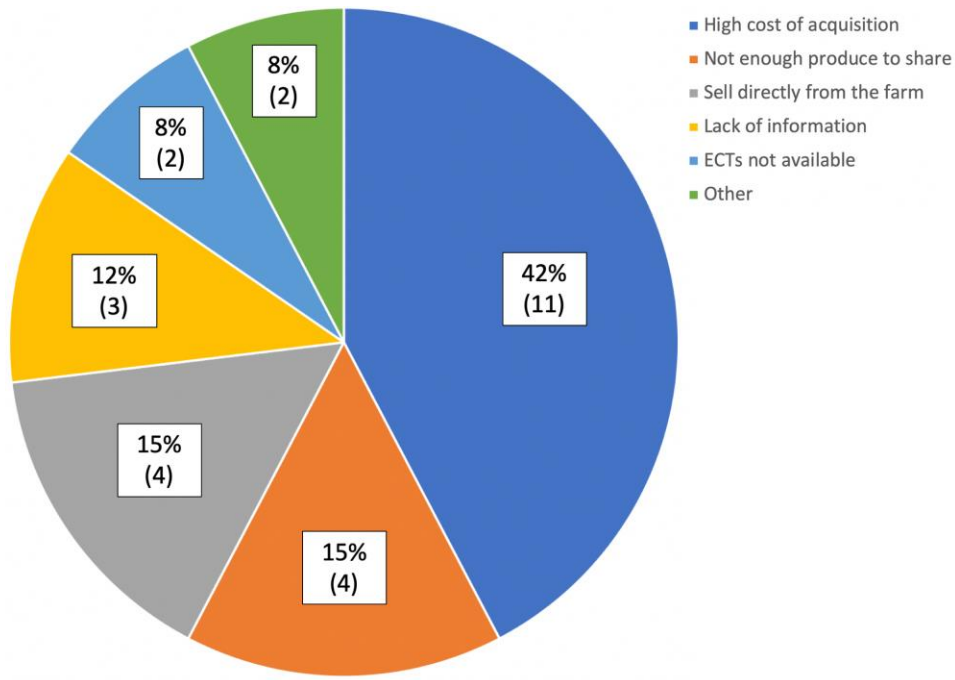

Figure 3. Primary reasons for not using any of the ECTs.

4.2.2 Benefits of use of ECTs

The two major benefits that the respondents associated with the use of ECTs are related to increased shelf life and aggregation of the fruit prior to sale. Increased shelf life reduces food losses, retains the quality of the fruit, allowing farmers to have more time to seek suitable markets and higher sales prices and income. Aggregation of produce by group members at a common point using the ECTs for storage allows for collective bargaining, which results to fair pricing and avoid exploitation by the buyers. A majority of the farmers individually sell their produce to middlemen who often manipulate the process in order to increase their gain along the marketing process. The collective selling allows bulk selling directly to exporting or processing companies other than through the middlemen.

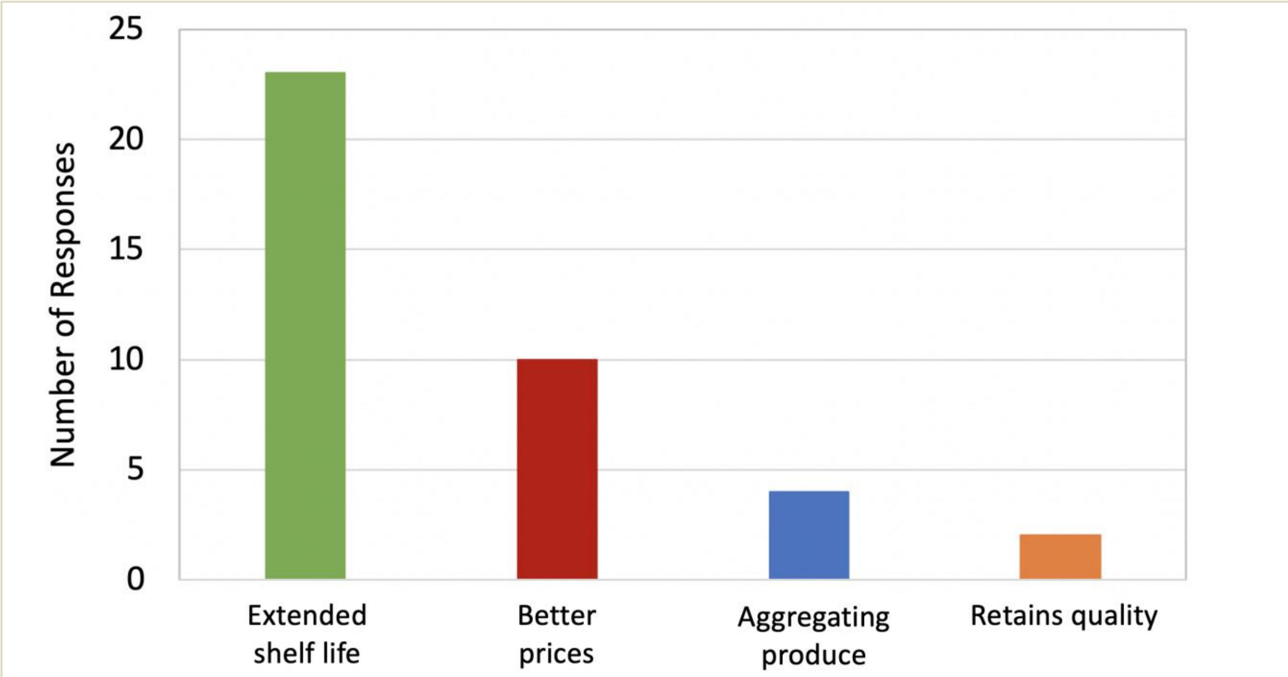

Figure 4. The benefits reported of ECT use.

4.3 Factors influencing use and non-use behavior

As mentioned, there are many factors that influence user adoption of a technology and/or behavior. Below are some of the factors identified to influence use and non-use behavior of ECTs among mango farmers:

- Level of education of the household head
- Main occupation of the household head
- Group membership
- Access to extension services
- Attendance of training and seminars

Table 3 shows a series of contingency tables to illustrate the correlations between various factors. The first column illustrates that being a member of a farming group significantly increases the likelihood that a farmer is aware of ECTs, with 43 of the

47 farmers (> 90%) that are members of farming groups being aware of ECTs, and less than half of the farmers interviewed that are not members of a farming group being aware of ECTs (16 out of 34). While being aware of ECTs is a prerequisite for using them, it is expected that the members of farming groups are more likely to be users. In addition to lower levels of awareness, the cost to construct and maintain an evaporative cooling chamber is typically too much for a single farmer to bear, particularly the larger capacity charcoal coolers. Thus, it is not surprising that all of the ECT users from this study are members of farming groups and they are using ECTs that are commonly owned by the farming groups and were built with external support; while none of the 16 respondents that were aware of ECTs were also users.

There are also strong correlations between membership in a farming group and access to attending trainings and extension services. Nearly 90% (41 of 47) of the members of farming groups reported having attended at least one training in the past 12 months, where only 12% (4 of 34) non-members had attended a training in the past 12 months. There is a similar, but less pronounced correlation between framing group membership and access to extension services, where only 2 out of the 34 non-members (6%) have access to extension services, while 45% (21 of 47) members of farming groups have access to extension services.

Table 3. Correlations between awareness of ECTs, membership in cooperative farming groups, attendance of trainings, access to extension services, and use of ECTs.

		Total	Are you a member of a farming group?		Do you use ECTs?	
			Yes	No	Yes	No
Total		**70%**	**58%**	**42%**	**32%**	**68%**
Are you aware of ECTs?	Yes	**73%**	53% (43)	20% (16)	41% (33)	32% (26)
	No	**27%**	5% (4)	22% (18)	0%	27% (22)

Do you use ECTs?	Yes	**32%**	41% (33)	0%	-	-
	No	**68%**	17% (14)	42% (34)	-	-
Are you a member of a farming group?	Yes	**58%**	-	-	41% (33)	17% (14)
	No	**42%**	-	-	0%	42% (34)
Have you attended training about mango farming in the last 12 months?	Yes	**56%**	51% (41)	5% (4)	38% (30)	19% (15)
	No	**44%**	6% (5)	38% (30)	3% (2)	41% (33)
Do you have access to extension services?	Yes	**30%**	27% (21)	3% (2)	22% (17)	8% (6)
	No	**70%**	30% (24)	40% (32)	18% (14)	53% (42)

Given that all of the ECT users are members of cooperative farming groups, we will look at the correlations between attendance of trainings, access to extension services, education, occupation, and use of ECTs among group members only.

Figure 5 shows the number of respondents that are users and non-users of ECTs as a function of having attended trainings of having access to extension services. Seventy-three (73%) of those who attended trainings or seminars during the previous 12 months were users of the technology while 40% of those who did not attend any training or seminar during the previous 12 months were non-users. These are trainings were organized by the cooperative groups and exposed the members of the group and therefore it is likely that those who attended training are members of the group. Access to extension services was found to have an influence on the use of ECTs. Eighty one percent (81%) of the individual who report being visited by an extension officer at least once during the previous 12 months, use ECTs whereas 58% of those who did not access extension services in the previous 12 months are users of ECTs. Although visits by extension service agents were not directly related to ECTs, the increased use of ECTs by those who have access to extension services and are made aware of new technologies in general may result in a greater willingness to adopt ECTs.

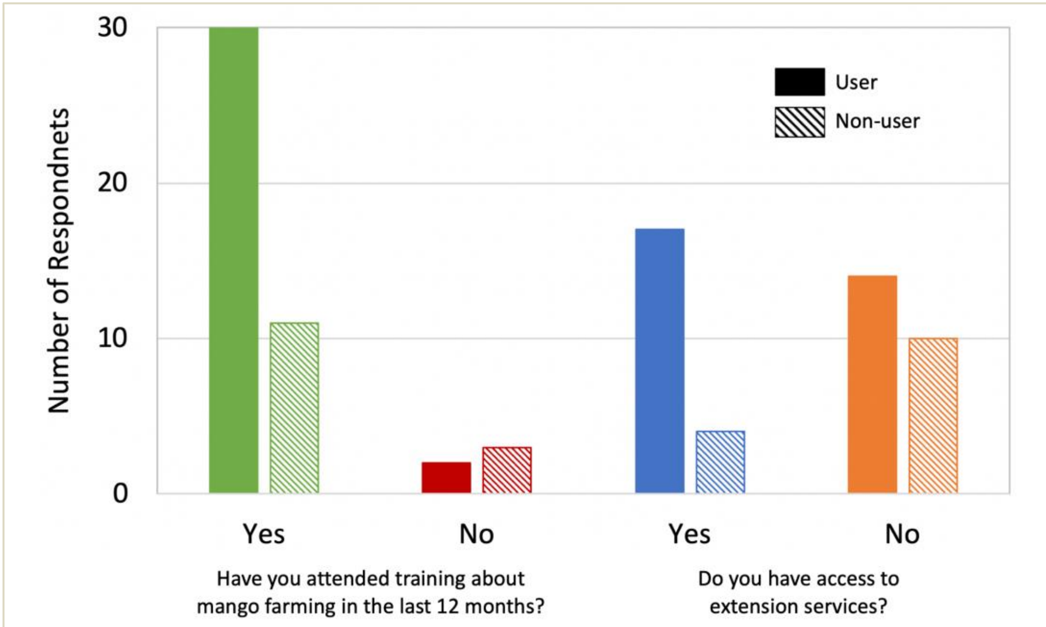

Figure 5. Comparison of users and non-users that are members of a cooperative that have attended trainings or have access to extension services.

Figure 6 below shows that among the group members, those with lower levels of education have higher proportions of non-users than users. Fifty percent (50%) of those with no education use ECTs, and is greater for those with higher education levels of education attained is increased, with 75%, 64%, and 89% for respondents with only primary education, secondary education, and tertiary education, respectively. Given the small same size for

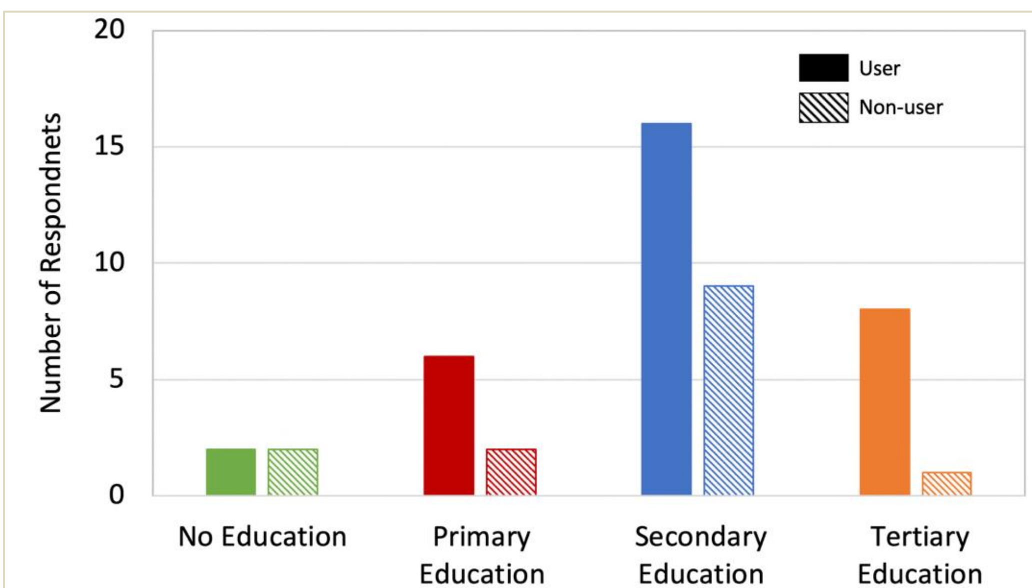

Figure 6. Difference between users and non-users that are members of cooperatives with various levels of education

Figure 7 shows that a majority of the ECT users have a main occupation of farmers, with 26 of those whose main occupation is farming use at least one type of the ECTs compared to 5 who are in other occupations and use ECTs. Farming is also the occupation with the highest usage of ECTs, with 70% (26 of the 37) of farmers interviewed using the ECTs. In contrast 56% of respondents with other occupations are users of ECTs.

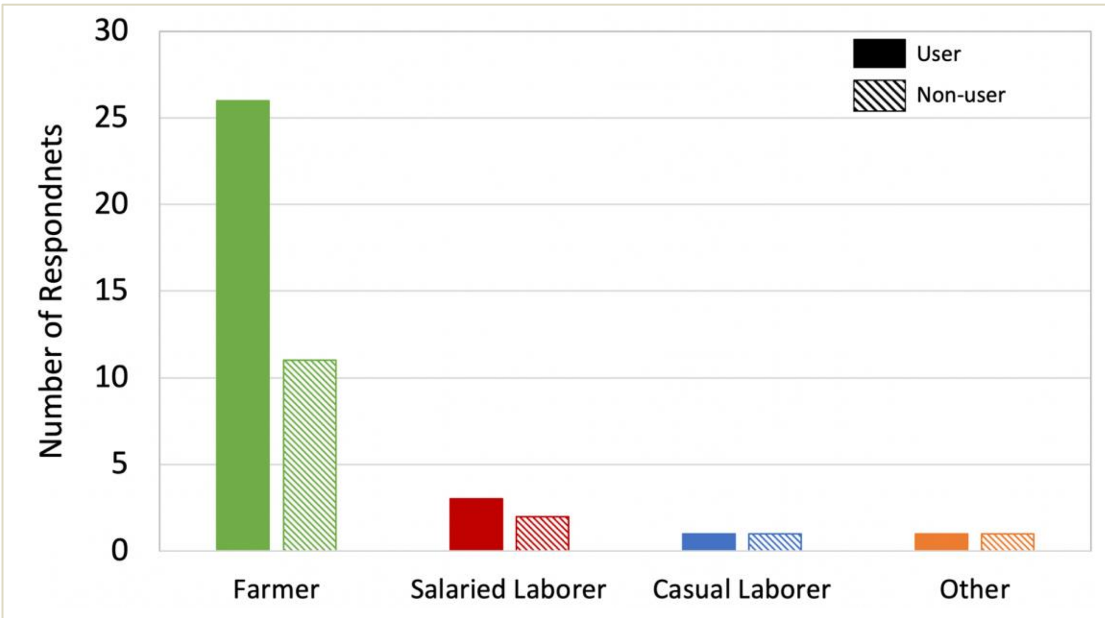

Figure 7: Difference between users and non-users that are members of cooperatives with respect to occupation

5.0 Conclusions and Recommendations

Among the farmers that participated in this study, 73% are aware of ECTs, and among this group 56% use at least one ECT. A majority of the respondents (58%) in this study belonged to a farmer group or cooperative. Membership to a farming group was the greatest determinant of awareness and usage of ECTs. All of the respondents in this study that are users of ECTs are members of a farming group, and the ECTs used were located at central locations and owned collectively by the farming groups. Having access to agricultural extension services and attending trainings related to mango farming also strongly correlated with farmers adopting ECTs. Among the non-users who were aware of ECTs, the reasons attributed to lack of adoption included high cost of acquisition and maintenance, lack of information, lack of access to ECTs, and a lack of need for storage to extend shelf life. None of the respondents individually owned an ECT, and the ECTs being used in both study areas were built with the help of government and non-government agencies, which is indicative of the cost barriers that must be overcome. Despite the barriers to ECT adoption, farmer groups who owned ECTs indicated that they benefited from their use, improving shelf life and reducing losses, increasing the time to look for markets, and increasing prices for their produce.

Based on the results of this study we recommend that the adoption and effective use of ECTs can be increased by taking the following actions:

- Improve ECT designs to enhance their performance, lower the cost, and better meet users' needs.
- Inform farmers of ECTs and their benefits, and provide training and support to ensure proper use and adoption. This can be done through seminars, farmer field days, and demonstrations for both group members and non-members.
- Leverage farming groups as pathways for disseminating ECTs. Emphasis should be placed on the important role of groups in accessing new and improved technologies as well as information access and the ease of accessing other services and privileges of being a member of a framing group.
- Increase access to extension services – both private and public – in order increase information availability of agricultural best practices in general for both group members and non-members. Extension agents can help gather information on what technologies are of the most interest and can provide the greatest benefits to farmers in a specific region.

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