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Transaction and Information Pain Points in African Indigenous Vegetable Value Chains in Western Kenya

A Gender-Responsive AIV Value Chain and Market Analysis Report

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About the Project

Exploring the Use of Blockchain Technology to Improve Food Security Through African Indigenous Vegetables in Western Kenya is one of the first projects undertaken to investigate how blockchain technology can be deployed in horticultural value chains with the express purpose of improving food and nutrition security among all AIV value chain actors. The project also focuses on understanding how digital platforms using BCT will secure the place of women and youth in the value chain. This report documents AIV value chain characteristics, gender and age dynamics, and pain points to identify where BCT may be an appropriate solution to improving value chain functionality. Additional information can be found on the project website. This project was made possible through a LASER PULSE grant, funded by USAID.

About LASER PULSE

LASER (Long-term Assistance and SErvices for Research) PULSE (Partners for University-Led Solutions Engine) is a five-year, $70M program funded through USAID's Innovation, Technology, and Research Hub, that delivers research-driven solutions to field-sourced development challenges in USAID interest countries. A consortium led by Purdue University, with core partners Catholic Relief Services, Indiana University, Makerere University, and the University of Notre Dame, implements the LASER PULSE program through a growing network of 2,500+ researchers and development practitioners in 61 countries.

About this Publication

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Abbreviations

AIV	African Indigenous Vegetables
BCT	Blockchain Technology
CBO	Community-based Organization
DDS	Diet Diversity Score
FIES	Food Insecurity Experience Scale
GoK	Government of Kenya
ICT	Information Communication Technology
KES	Kenyan Shilling
LASER PULSE	Long-term Assistance and SErvices for Research Partners for University-Led Solutions Engine
LMIC	Low- and Middle-Income Country
MoALF	Ministry of Agriculture, Livestock, and Fisheries
PVCA	Participatory Value Chain Analysis

Executive Summary

The use cases for blockchain technology (BCT) have taken off since its initial development for the cryptocurrency Bitcoin. In agricultural value chains, BCT solutions have been developed to increase transparency and traceability from source to point of sale and to create secure transaction platforms. However, BCT is not a magic bullet for addressing all value chain inefficiencies and challenges. This study, *Exploring the Use of Blockchain Technology to Improve Food Security Through African Indigenous Vegetables in Western Kenya,* aims to investigate the types of challenges within the value chain for African indigenous vegetables (AIVs) that BCT is appropriate to address. Specifically, we are interested if a BCT-based digital platform will lead to improved functionality and if this in turn will lead to improved food security for all value chain actors.

This gender-responsive participatory value chain analysis (PVCA) investigates the transactional, informational, and other types of pain points within AIV value chains that inhibit functionality and efficiency to identify where BCT could be used as a solution. Since AIVs are known as 'female' crops, as women are primarily responsible for their production, marketing, and preparation, this PVCA investigates gender disparities in the value chain to understand how a BCT-based digital platform might help to secure the place of women in the value chain as it is upgraded.

According to the findings of the PVCA, the main pain points that need to be addressed in order to improve the functionality of AIV value chains are the lack of coordination throughout the value chain, lack of assurance of vegetable safety for consumers, poor transmission of information through the value chain, no standardized grading and pricing, weak market power of women, and need for technical assistance for producers in pest and disease management and production practices to improve yield. Addressing these constraints could lead to improved food security by increasing the income of value chain actors and increasing the demand for AIVs.

BCT cannot address all the pain points and inefficiencies identified. However, it is well suited for improving vertical coordination between actors by organizing and standardizing transactions and making information on the AIVs accessible at all stages of the value chain. It will also provide women a safe and secure platform for transacting that will protect the revenues earned from their respective activities. This study also finds that while smartphone ownership is low, value chain actors are willing to pay for a smartphone as well as a monthly subscription fee to use a digital platform if it will address their key pain points.

This study will continue to investigate key knowledge gaps such as how technology use might more effectively engage youth in AIV value chains, how information on the blockchain can be certified, and how to scale up the use of a BCT-based digital platform. However, this PVCA demonstrates there is potential for BCT to offer important solutions to address transactional and informational inefficiencies along AIV value chains.

Introduction

African indigenous vegetables (AIVs) are recognized as a food security crop in Kenya and other East African countries. In addition to offering rich micronutrient content and other health benefits, AIVs have short growth cycles and their production is relatively simple thus creating viable income-earning opportunities for small-scale and landless laborers. As market opportunities for the leafy greens are growing, AIV production is becoming increasingly lucrative. However, economic and nutritional gains from AIVs have not yet been fully realized, particularly in rural Kenya, due to inefficiencies and bottlenecks in the value chains and wider food system (Mwangi and Crewett 2019). According to Bokelmann, Ferenczi, and Gevorgyan (2016), AIV value chains are characterized by information asymmetry, a lack of trust and transparency within transactions, and ineffectively matched supply and demand. Identifying solutions to address these constraints will help small-scale producers and other value chain actors capture the economic and nutritional benefits of AIVs. Consumers of all income levels will also be able to access desired AIV varieties and the AIV characteristics they value at an acceptable price point.

Blockchain technology (BCT) may offer a solution to address the information and transactional inefficiencies within AIV value chains. BCT's characteristics (i.e., immutable and distributed ledgers, a tamper-proof blockchain), are designed for contexts where trust, transparency, and security of transactions are low, access to trustworthy market information is limited, and transaction costs are high (Roeck, Sternberg, and Hofmann 2019). Emerging evidence suggests that smartphone applications built on BCT can improve value chain functionality to increase the incomes of cash crop farmers (e.g., coffee, cocoa). Further research is needed to understand if BCT is a viable technology for agri-food value chains that are more informal and dispersed and if it can contribute to improvements in food security. This research project, *Exploring the Use of Blockchain Technology to Improve Food Security Through African Indigenous Vegetables in Western Kenya,* aims to investigate the pain points that a BCT-based digital platform developed by AgUnity Pty Ltd can address to improve AIV value chain functionality and increase food and nutrition security for all value chain actors including consumers. The research focuses on priority populations including small-scale producers, low-income consumers, women, and youth.

The first phase of this research study consisted of a gender-responsive participatory AIV value chain analysis conducted in Kakamega County, western Kenya. The objectives of this phase were to:

1 - Identify transactional, informational, and other pain points that inhibit income generation, diminish supply, and/or contribute to low consumption of the four main varieties of AVIs
2 - Investigate the level of AIV purchase among consumers
3 - Understand the level of food security and dietary quality among AIV value chain actors, including consumers
4 - Specify the proliferation of smartphone usage and ownership among the study population
5 - Explore AIV actors' willingness to adopt smartphone technology into their operations

The findings of this initial phase were used to adapt the AgUnity digital platform for the AIV value chain in Kakamega County. More information on this research and results from the deployment of the platform with targeted value chain actors can be found on the project website.

Background

African indigenous vegetables (AIV) refer to plants that are native to Africa whose leaves, roots, fruits, and seeds are part of the cultural and locally accepted diet. With more than 200 known indigenous plant varieties, the popularity of specific varieties depends on the region. In western Kenya, the most popular varieties are cowpea leaves, amaranth, jute mallow, African black nightshade, and spider plant (Box 1). AIVs are rich in micronutrients that are essential for human health and development and are often more nutrient-dense than other 'exotic' vegetables not native to Africa (e.g., cabbage, tomatoes) (Lotter et al. 2014). For example, amaranth has more than 55 times the amount of vitamin A compared with cabbage (Yang and Kedding 2009). Certain AIV varieties such as pumpkin leaves, amaranth, and moringa, are known to also have medicinal properties. For example, pumpkin leaves are used to mitigate hypertension and reduce oxidative stress in the body (Ishiekwene et al. 2019). Beyond their nutritional benefits, AIVs offer high returns to labor, a short growing cycle that can be incorporated into a year-round production system, and higher farm-gate values per unit area than other types of cash crops (i.e., maize, sunflowers). The leafy greens are known as 'female crops' as their production and marketing are largely dominated by women (Kansiime et al. 2018).

Box 1. Most popular AIV varieties

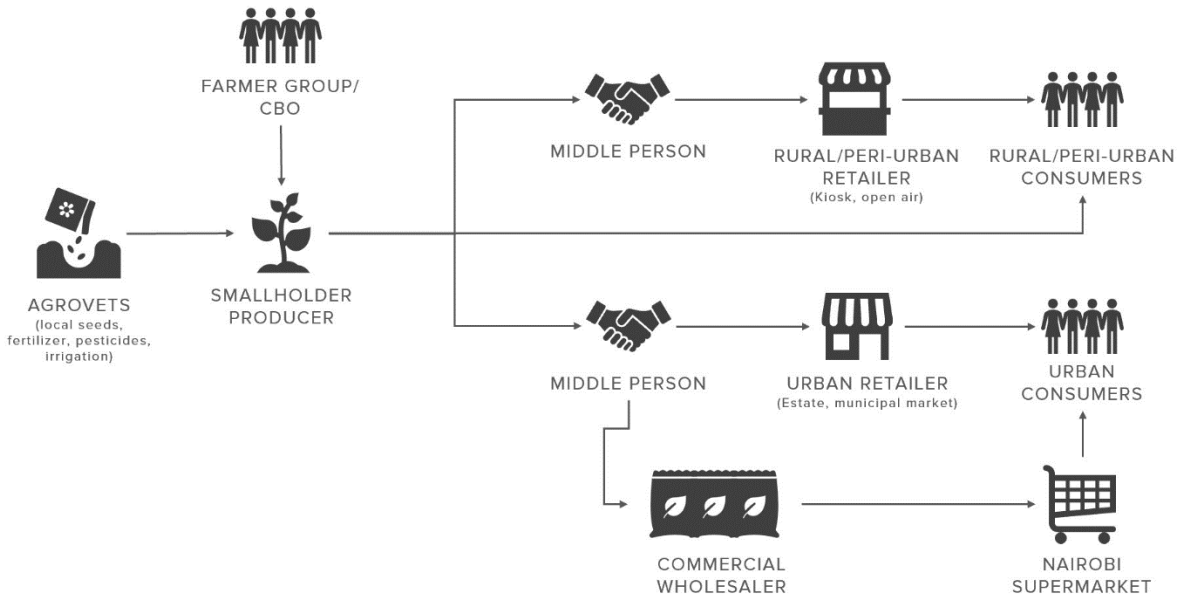
Note: Spider Plant Photo Credit: USAID Kenya Agricultural and Livestock Research Organization

The decline in AIV production in Kenya and other east African countries resulted from increased pressure on small-scale producers to grow cash crops such as maize and sugarcane. This was compounded by changes in food habits and environmental changes that created inhospitable

growing conditions for horticultural crops. Fortunately, in the last decade, there has been a resurgence in focus on AIVs among researchers, nutrition practitioners, and consumers given their cultural and nutritional significance and economic potential (Uusiku et al. 2010). Yet, AIVs' contribution to food and nutrition security will only be realized when the functionality of their value chains is improved. This will require increasing the productivity of AIV varieties that are highly desirable by the consumer, reducing post-harvest losses and loss of quality during transportation, transmitting market and vegetable information along the value chain, improving value chain governance, creating mechanisms to match supply and demand in the market, and understanding the factors that influence consumer acceptance and willingness to pay for AIVs (Gido, Bett, and Bokelmann 2016).

Several value chain analyses have been conducted in Kakamega to map the flow of vegetables from producer through to the consumer, understand the behavior of actors, investigate the nature of relationships between actors, and identify obstacles to value chain functionality (see for example (Abel et al. 2019; Weinberger and Pichop 2009; Ngugi, Gitau, and Nyoro 2006)). In the most recent of these studies, Abel et al. (2019) find that "on the whole, the value chain for [AIVs] in Kenya [is] replete with weak producer collective action towards marketing, incapable of fostering beneficial vertical coordination with buyers." Figure 1 depicts the value chain as described in the AIV literature specific to Kakamega county.

Figure 1. Hypothesized AIV value chain structure



Producers of AIVs are usually small-scale, and often sell only the surplus vegetables from their kitchen gardens that are not consumed by the household. Rural producers, in particular, tend not to use productivity-enhancing processes at all, while peri-urban producers may use improved seeds, fertilizers, or some pesticides to improve yields. When inputs are used, they are obtained from

agrovet dealers, neighbors, or are produced by the farmer themselves. In general, knowledge on how to improve productivity and quality is relatively basic. Producers lack knowledge on how to improve productivity and quality, are unfamiliar with value addition processes that meet the demands of consumers, and struggle to overcome some of the key obstacles to maintaining the right levels of supply for the market (Gido, Bett, and Bokelmann 2016; Abel et al. 2019). As a result, productivity is low and post-harvest losses are high (Gogo et al. 2017). Farmer groups assist producers in acquiring skills to improve productivity through technical assistance and training; however, they usually do not assist in marketing or helping producers to improve their market power or profit margins.

Value chains for AIVs are relatively short, passing from producer through a middle person to a retailer of vegetables in local markets. Middle people (i.e., traders) add little if any value to the vegetables other than to transport them from the farm gate to the retailer. The relationship between small-scale producers (usually women) and middle people (usually men) tends to be characterized by opportunistic behavior on the part of middle people, especially in high-value markets. Market information is generally not shared with producers. Though there are opportunities for upgrading, farmers do not have adequate information on the varieties and characteristics most demanded by consumers to capture the higher price points these opportunities offer. Some traders may use this to their advantage to suppress prices paid to producers (Abel et al. 2019; Gido et al. 2017). While value chain governance is weak, it is not the case that all traders take advantage of the lack of market power held by small-scale producers. For example, some traders will enter into oral contractual agreements with farmers where they pay for unharvested vegetables. In the case of higher value markets where the vegetables are sold in supermarkets in Nairobi, contract values are estimated based on prevailing market prices and project yield estimates, resulting in middle people assuming the majority of risk (Abel et al. 2019).

There are mixed findings on the extent of AIV demand among Kenyan consumers, especially those most vulnerable to micronutrient malnutrition. There is evidence of significant and growing demand for several AIV varieties (i.e., amaranth, cowpeas, and African black nightshade) – see, for example Gido et al. (2017, 2016); Gido, Bett, and Bokelmann (2016). Other evidence shows low demand that stifles the potential for the crop to become a major source of income for small-scale producers (Mwangi and Crewett 2019). Gido et al. (2017) clarify the discrepancy – i.e., consumption and preference for AIVs are based on the cultural context. The authors contend that while AIV demand has been growing, there are negative perceptions and concerns about the way vegetables are grown or processed that inhibit consumption at a level that would have positive nutritional impacts. These concerns usually vary based on the rural, peri-urban, and urban context (Gido et al. 2017; Gido, Bett, and Bokelmann 2016).

Another barrier to sufficient AIV consumption is the mismatch of supply and demand in the market since it creates periods of glut and scarcity. Oversupplied vegetables typically are not of the varieties that the consumer is looking for because the producer does not have access to quality market information. This leads to consumer frustration as they are unable to find the varieties they need.

According to Gido et al. (2016), increasing consumption of AIVs to levels that would have positive nutritional outcomes could be achieved by ensuring the desired varieties are available at the consumers' preferred retail outlets.

The main value chain inefficiencies that constrain the contributions that AIVs make to food and nutrition security are an insufficient flow of information through the value chain, mismatched markets, poor vertical coordination between actors, and a lack of trust and transparency. The characteristics of BCT are well suited to address these factors. BCT is one implementation of distributed ledger technology that processes, validates, and authorizes transactions in multiple copies of an immutable record. Its potential application is extensive. Most notably, it provides the underlying structure for Bitcoin and other cryptocurrencies. It also offers potential solutions to the manufacturing, energy, utility, and healthcare sectors. Increasingly, agricultural supply chain solutions are being developed on the blockchain to increase consumer trust in the quality and safety of the final product by generating information about the products from farm to point of sale (FAO 2019).

Despite all that it offers, BCT is not a panacea for addressing the dysfunctionality of agri-food value chains. There are several requirements to determine if BCT is an appropriate type of information and communication technology (ICT) for reducing value chain inefficiencies in a way that supports food and nutrition security.

1 - BCT is used to verify transactions between two parties. Therefore, value chain actors that transact with one another must each have access to or own a smartphone that supports blockchain-based transactions.

2 - Access to immutable and secure data can create consumers trust and interest in purchasing AIVs. BCT helps verify traceability that strengthens trust in the value chain. When combined with education on nutritional benefits and ways to prepare the vegetables, if the transparency that BCT can provide is important to consumers when making then the technology may help to increase consumption of AIVs.

3 - There must be a way to verify and certify the information being added to the blockchain is accurate and uncorrupted.

4 - Any digital platform and proposed solution will need to ensure that one group is not made worse off since the use of digital platforms requires cooperation between actors. This is especially important in a weak institutional environment where participation cannot be monitored or enforced. Small-scale agriculture is also characterized by fragile livelihoods, even among traders and retailers. Disrupting the income of any one type of value chain actor could have serious consequences on income and quality of life.

There is still little known about the contexts in which BCT-based digital platforms meet these requirements in an LMIC context. This value chain report describes the value chain in detail to identify the viability of a BCT-based digital solution and the pain points it could most effectively address.

Methodology

Participatory value chain analyses (PVCA) seek to engage value chain actors to understand the nature of relationships and behavior within a value chain rather than just identifying technical constraints or problems. It does this by seeking feedback on hypotheses and findings from various actors throughout the data collection and analysis process. This PVCA specifically focused on understanding how relationships and behavior within the value chain affect transactions, the flow of information on the AIVs from producer to end consumer, and other activities undertaken at each stage. Both quantitative and qualitative data were collected. The research protocol and all data collection instruments were approved by the Biomedical Research Alliance of New York (Protocol No. 20-059-568) and the Egerton University Research Ethics Committee (Approval No. EUREC/APP/113/2021).

Study Area

Kakamega County is located in western Kenya, near the border of Uganda (Figure 2). In 2019, the population was approximately 1.8 million (GoK 2019). As of 2016, the absolute poverty rate was approximately 36%, compared to the national average of 37%, and the rate of food poverty was approximately 33%, compared to the national average of 32% (GoK 2017). Kakamega is one of four counties that has the highest rate of multi-dimensional and monetary poverty in absolute numbers in the country (KNBS 2020).

Figure 2. Kakamega county

Source: https://kenya.opendataforafrica.org/

The county's economy is primarily driven by agriculture, specifically crop and livestock production. The main crops produced in the county are maize, sugarcane, bean, cassava, finger millet, and sorghum (MoALF 2017). Because of its agro-ecological zones, Kakamega County is one of the major producers of AIVs in Kenya as horticultural production can take place throughout most of the year (Laibuni, Losenge, and Bokelmann 2020). Most vegetable production is carried out by small-scale producers (MoALF 2017). Accordingly, irrigated agriculture and horticultural production are core strategies for reducing poverty in the region (County Government of Kakamega 2018).

The PVCA was carried out in three sub-counties of Kakamega – Mumias West, Mumias East, and Butere – and Kakamega Town proper. These study locations were selected as they each produce significant volumes of AIVs and have varying vertical coordination arrangements between producers, traders, and retailers. Kakamega town was also selected as it is a key destination market for vegetables from the three sub-counties.

Data Collection

Before the data collection instruments were finalized, a scoping trip was conducted in November 2020. Key informant interviews were conducted with the local community-based organization (CBO), *New Vision*, the extension office of the Ministry of Agriculture, Livestock, and Fisheries (MoALF), the Ministry of Youth and Information Communication Technology (MYICT), and traders and retailers of AIVs to understand the local context, identify the critical stakeholders for the data collection phase, and make connections with local contacts. The local county government was informed of the study and the necessary approvals for the study were obtained. Subsequently, a value chain questionnaire, focus group discussions, and immersive research were carried out in January and February 2021.

Sampling

PVCA sampling is not intended to be representative, rather, participants that can contribute high-quality and detailed information through semi-structured interviews are purposively selected (USAID n.d.). Producers were identified through connections with the local CBO, New Vision, MoALF extension workers, and snowball sampling. Traders and middle people were identified and recruited following the morning selling period in markets within each county. A similar process was used to identify and recruit retailers and consumers.

Questionnaire

A structured survey was conducted with 322 value chain actors – 199 producers, 20 middle people, 26 retailers, and 77 consumers (Table 1). Specific modules for each actor investigated their basic functions and responsibilities, gender dynamics, flow of information, the nature of transactions, and levels of trust in the relationships between actors. The actor-specific modules also investigated the pain points that actors face in carrying out their respective activities in the AIV value chain. Modules conducted with all actors included socio-economic and demographic factors, technology use, food security, and diet diversity. The questionnaire was based on previously conducted value chains to test the findings of previous studies.

Table 1. Questionnaire respondents by value chain role and gender

Value Chain Actor	Gender	Number of Respondents
Producers	Female	140
	Male	59
Middle People	Female	20
Retailers	Female	24
	Male	2
Consumers	Female	57
	Male	20

Focus Group Discussions

Focus group discussions (FGDs) were conducted with 104 participants. Groups were separated into producers, traders, retailers, and consumers to deepen the understanding of the pain points in carrying out their respective roles in the value chain, seasonality of AIV production, trust between actors, and receptiveness to AgUnity's blockchain application. FGDs were separated by gender and facilitated by Egerton faculty of the corresponding gender. Twenty FGDs were conducted in total.

An ice breaker gathered the opinions of participants on the structure of the hypothesized value chain developed from existing literature. Facilitators then investigated the seasonal patterns of value chain functions, actors' day-to-day lives, weather, saving patterns, disease, food security and nutrition, holidays and celebrations, and emotional responses (i.e., happy, stressed). The facilitators subsequently mapped the 'user experience journey', a critical tool used by AgUnity to tailor their digital platform to specific user groups. This activity explored planting and pre-harvest, harvest, and marketing activities as well as saving practices, gender norms, thoughts and feelings in each stage, and other types of touchpoints (i.e., interactions in the market or other specific activities). Subsequently, the perception of the AgUnity app was investigated and a willingness to pay bidding game was conducted with the participants. The final activity of the FGD was to map the positive and negative trends faced by participants, their hopes and fears, headaches, needs, and opportunities.

Immersive Research

Immersive research was conducted by three Egerton University students, who were hosted by small-scale producer households. Students stayed in the producer's homes for three days. They participated in the day-to-day activities of the producers' households to better understand the challenges they face, their day-to-day activities, and a deeper understanding of the nature of their lives. This is a common practice used by AgUnity in the app-development phase and helped to enrich the understanding of the AIV value chain and environment in which it operates.

Value Chain Analysis

AIV Core Processes

The activities undertaken by each of the actors in the AIV value chain are summarized in Figure 3. At each stage of the value chain, actors use simple processes to preserve the freshness of the vegetables, minimize losses, and maintain the quality that the consumer demands; however, very little value addition or transformation occurs between producer and consumer. New Vision, a CBO in Kakamega, has been experimenting with vegetable drying to try to reduce the income lost from post-harvest losses and reduce the fluctuations in vegetable supply resulting from the highly weather-dependent nature of production. Unfortunately, there is currently very little demand for dried vegetables as consumers do not know how to use dried vegetables in traditional recipes.

One of the biggest challenges faced by all actors as they carry out their respective activities is maintaining the freshness of vegetables. In addition to profitability and consumer willingness to pay, the length of time between harvest and consumption and the packaging method significantly affects the micronutrient content of the vegetables (Gogo et al. 2017).

Table 2. Core AIV processes

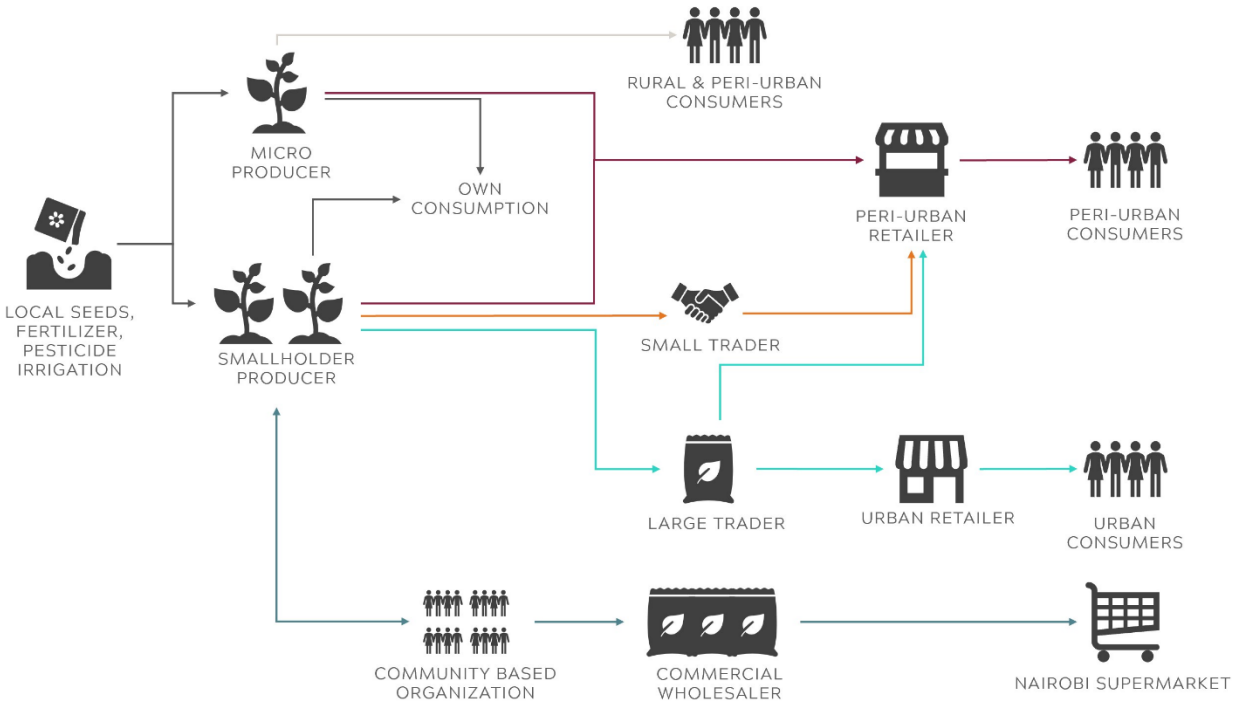
	Inputs	Production	Trade	Retail	Consumption
Actors	Producers Agrovet Dealers	Micro and small-scale producers	Small and large volume traders CBO	Stall operators at wet and municipal markets	Households in Kakamega, producers, traders, retailers
Activities	Seed saving Manure saving Compost production Purchasing inputs from dealer Irrigation if the equipment is available	Preparing field Planting Weeding Irrigating Harvesting Cutting roots from stalks Wash the majority of dirt off the vegetables In rural/peri-urban areas, producers may transport their vegetables directly to the retailer	Aggregating Bundling Washing if not done well by the producer Packaging into gunny bags Transport to market Small volume traders may also be producers	Vegetables are washed for a final time Broken down into smaller bundles Vegetables may be shredded and packaged into bags Retailers may also be producers	Vegetables are commonly boiled then fried with other vegetables (e.g., tomatoes) Milk is usually added Commonly consumed with ugali May be eaten with meat or beans

Value Chain Material Flows and Actors

The transfer of vegetables between value chain actors is shown in Figure 4. The analysis confirms the hypothesis that there are different vertical coordination arrangements between value chain actors based on the size and locality of the final market. The sub-chain types are delineated by colored pathways in the figure below. Micro producers tend to supply rural or peri-urban consumers (gray) or peri-urban retailers directly (maroon). Small-scale producers are more likely to sell their produce to a trader. Middle people transacting in small volumes tend to supply peri-urban markets (orange), while those transacting in larger volumes may sell to peri-urban and/or urban markets (light teal). The CBO, *New Vision,* not only provides training and technical assistance to their farmers but has

marketed the vegetables in Nairobi through a commercial wholesaler (turquoise). All value chain actors keep a portion of the AIVs for their own household's consumption. Additionally, it is common for retailers to produce and sell their AIVs alongside other producer's vegetables.

Figure 3. AIV value chain in Kakamega county



Producers

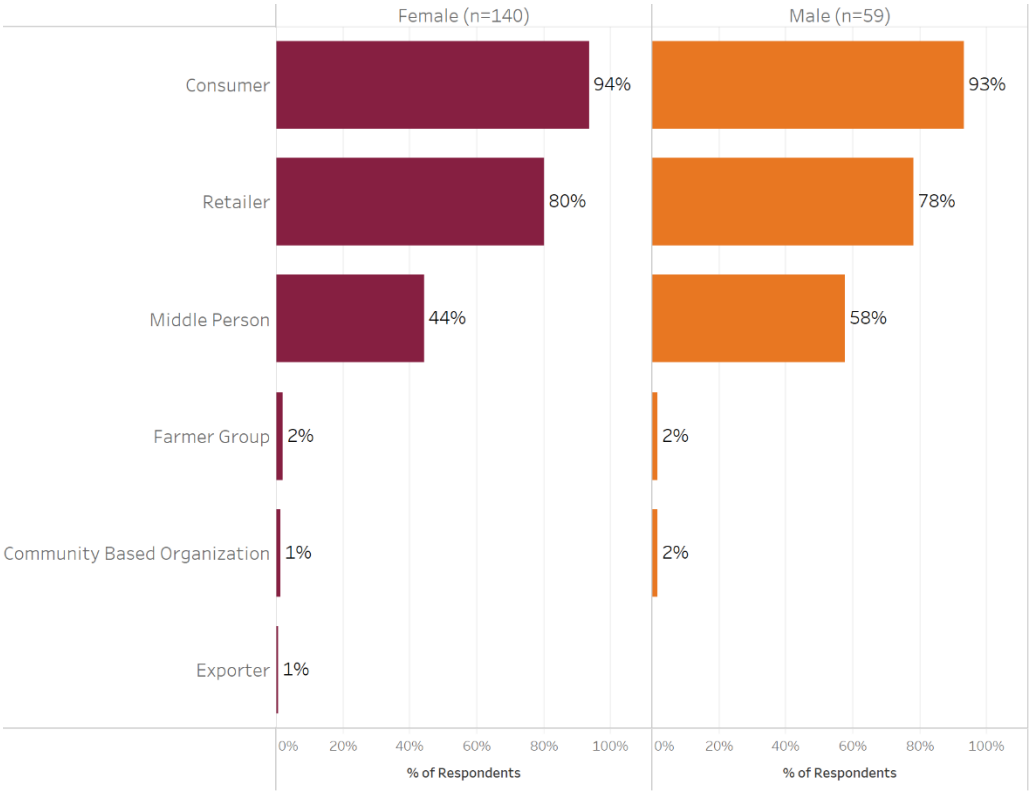
Micro producers harvest an average of two 50kg bags of AIVs every two weeks during peak vegetable growing seasons. The peak growing seasons correspond with the two rainy seasons in Kenya, the short rains (September/October) and the long rains (March/April/May). These producers typically sell the AIV surplus from their kitchen gardens, known as 'chambas'. Approximately 51% of producers (n=101) grow one acre or less. Small-scale producers (n=98) grow vegetables on one to six acres. Producers of AIVs tend to be women (70%), of whom 35% are middle age. Only 4% of producers were classified as youth (<30 years of age). The most commonly produced AIV varieties are amaranth, cowpea leaves, African black nightshade, sun hemp, jute mallow, and spider plant.

Most male and female producers sell directly to consumers and retailers (Figure 4).[1] A higher proportion of male producers (58%) sell to middle people than female producers do (44%) (p-value: 0.071). Producers generally do not always sell to the same people, citing convenience as the primary reason for working with a seller. Only about 25% of producers indicate that a long-term relationship with a seller is the primary reason for selling to them. A larger proportion of women sell to someone based on their relationship (28%) compared to men (15%) (p-value: 0.05), while more men may sell

[1] There is no significant difference between the proportion of male and female producers that sell to consumer and retailers (p-value: 0.7908).

based on convenience (76% of male producers compared to 68% of female producers); however, the difference is not statistically significant (p-value: 0.259). The majority of sales happen at the farm gate or the market.

Figure 4. AIV sales by buyer type



Middle People

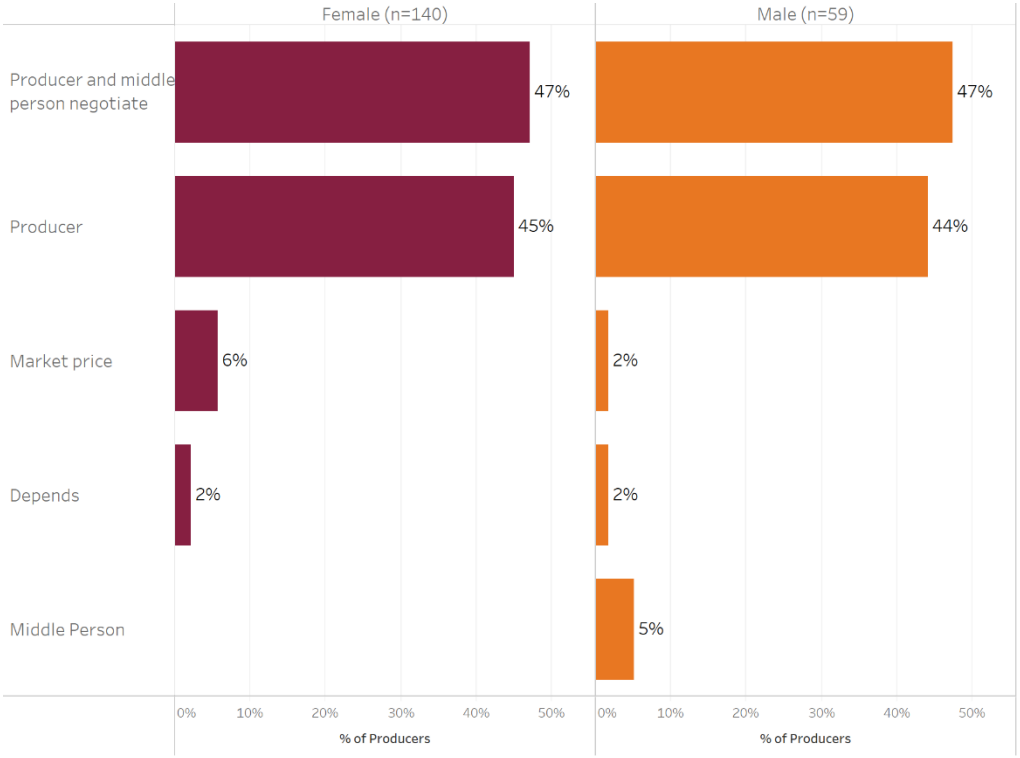
All middle people interviewed were women. Only one middle woman was classified as a youth (<30 years of age) and the rest were classified as middle age (30-55 years of age). The FGDs, however, indicate that it is more common for men to be large traders and commercial wholesalers, as men tend to transact in larger volumes.

AIVs represent 80% of middle people's trade and generate an average revenue of approximately 11,000 KES per month (~US$102). The majority of traders (85%) purchase vegetables either daily or every other day. Some traders also purchase from other middle people (65%). All middle people buy and sell African Black Nightshade, Amaranth, and Cowpeas. Jute Mallow and Spider Plant are also commonly traded varieties (90%) whereas Ethiopian Kale is somewhat less popular (70%). Middle people primarily purchase from producers within Kakamega County (80%), suggesting that Kakamega's AIV production is generally able to meet local demand.

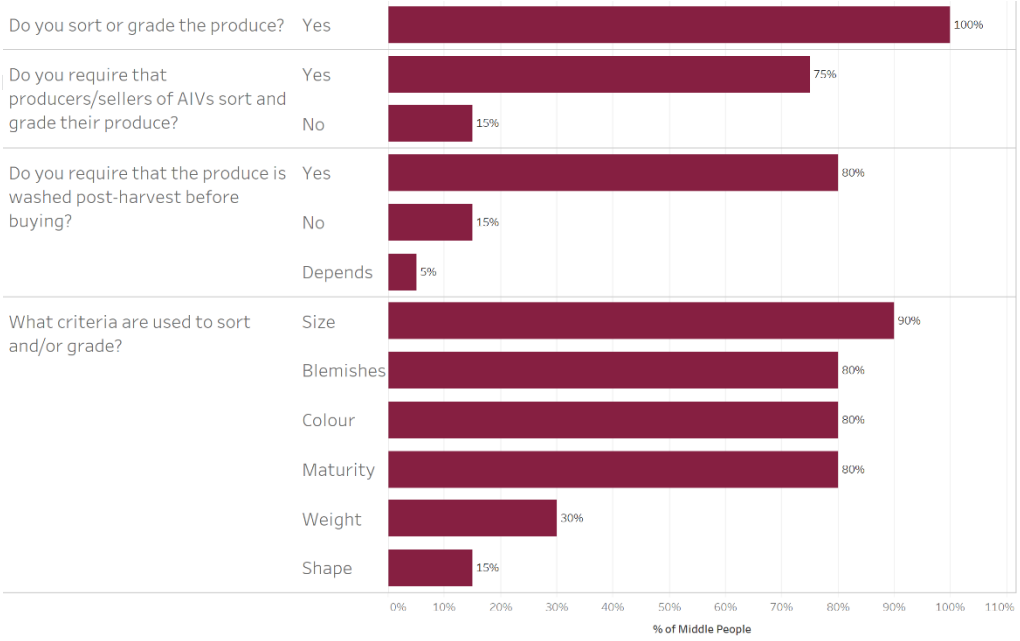
Producers are generally paid on the spot and the price is decided by mutual agreement or by the producer (Figure 5). Five percent of male producers indicate that the middle person may decide the

price. There are no significant differences in price setting control between male and female producers.

Figure 5. Price negotiation between producers and middle people



All middle people grade the AIVs they purchase from producers (Figure 6). Seventy five percent of middle people also require the producer to sort or grade AIVs before purchase. The most common criteria used to sort and grade AIVs are the size of the leaves, blemishes, color, maturity, and weight. Eighty percent of middle people require producers to wash the vegetables prior to purchase; for 5%



of retailers they only require that vegetables are washed in the rainy season. However, in the FGDs, middle people revealed that the grading process is not formal or consistent and that the grade is not formalized by retailers or communicated to the consumer. Middle people report between 1 and 20% loss in vegetables between purchase and the point of sale to consumers and/or retailers.

Retailers

Retailers of AIVs are generally women; all retailers surveyed (n=26) were women except two. The majority of retailers were classified as 'middle age'; only one male retailer was classified as a youth. Typically, retailers buy either from producers or middle people, using the market or word of mouth/mutual connections to find the AIV varieties they are looking for. AIV sales generate an average revenue of 33,000 KES per month (~US$306).

Amaranth, cowpeas, and jute mallow are the most common AIV varieties sold by retailers. However, retailers believe that African Black Nightshade is more popular with consumers than cowpeas and jute mallow (Figure 7). This confirms feedback from consumers, focus group participants, and key informant interviewees that the supply of popular AIV varieties does not meet demand. Approximately 30% of retailers did not know which varieties were popular with consumers.

Figure 7. Varieties sold and popular with consumers

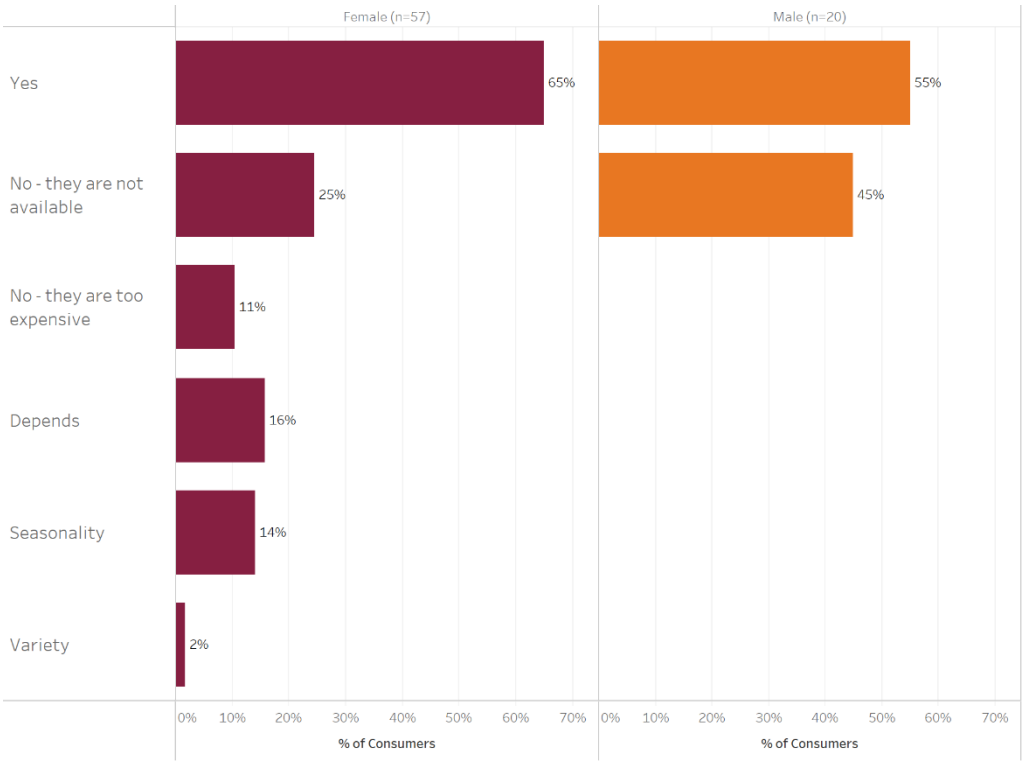
It is most common for the retailer to determine the price (62%). Only 18% of retailers indicate that they negotiate with the seller for the price and 15% indicate the seller dictates the price. Prices are

primarily decided at the point of sale (89%); 4% of retailers indicated that prices are decided at the time of harvest. Producers or middle people are typically paid on the spot. Some middle people allow retailers to pay them at the end of the day once the vegetables are sold, depending on the relationship between the retailer and the middle person.

Consumers

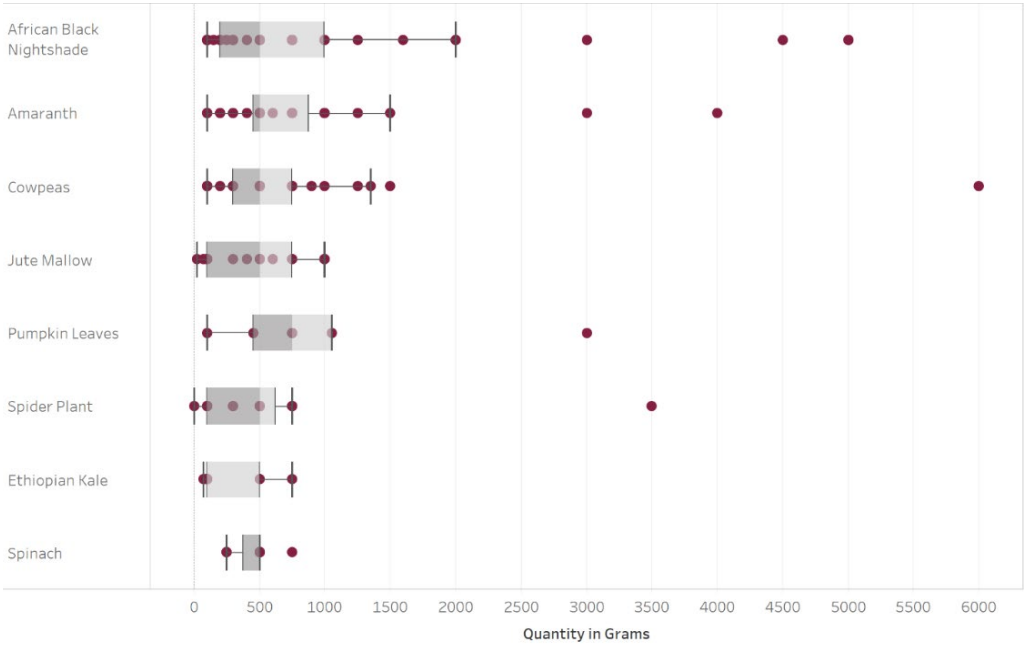
Of the 77 market shoppers interviewed, 26% were male, 73% were middle age, and 20% were youth. The FGDs, immersive research, and consumers indicate that women primarily shop for food, AIVs in particular. Most consumers indicate that they are able to find the variety of AIVs that they are looking for in the market (62%). Figure 8 suggests that a greater proportion of female consumers (65%) can find the varieties they are looking for in the market compared to male consumers (55%); however, this difference is not statistically significant (p-value: 0.43). Contrary to producers' indication that they sell directly to consumers, only 8% of consumers indicate that they purchase AIVs directly from producers. Most commonly, consumers purchase AIVs from either small or large retailers (80%). This may suggest that consumers either purchase directly from producers or the market.

Figure 8. AIV availability in the market



Consumers spend between 10 and 2,000 shillings on AIVs per week depending on the variety. The amount a consumer purchases ranges from 20 grams to 6 kg (Figure 9). As suggested by retailers (Figure 7), amaranth, African black nightshade, and cowpeas are among the more popular varieties with consumers. Retailers believe that spider plant is a popular variety; however, Figure 9 shows that the quantity in grams purchased on average per week is one of the lowest across varieties.

Figure 9. Quantities of AIVs purchased per week in grams



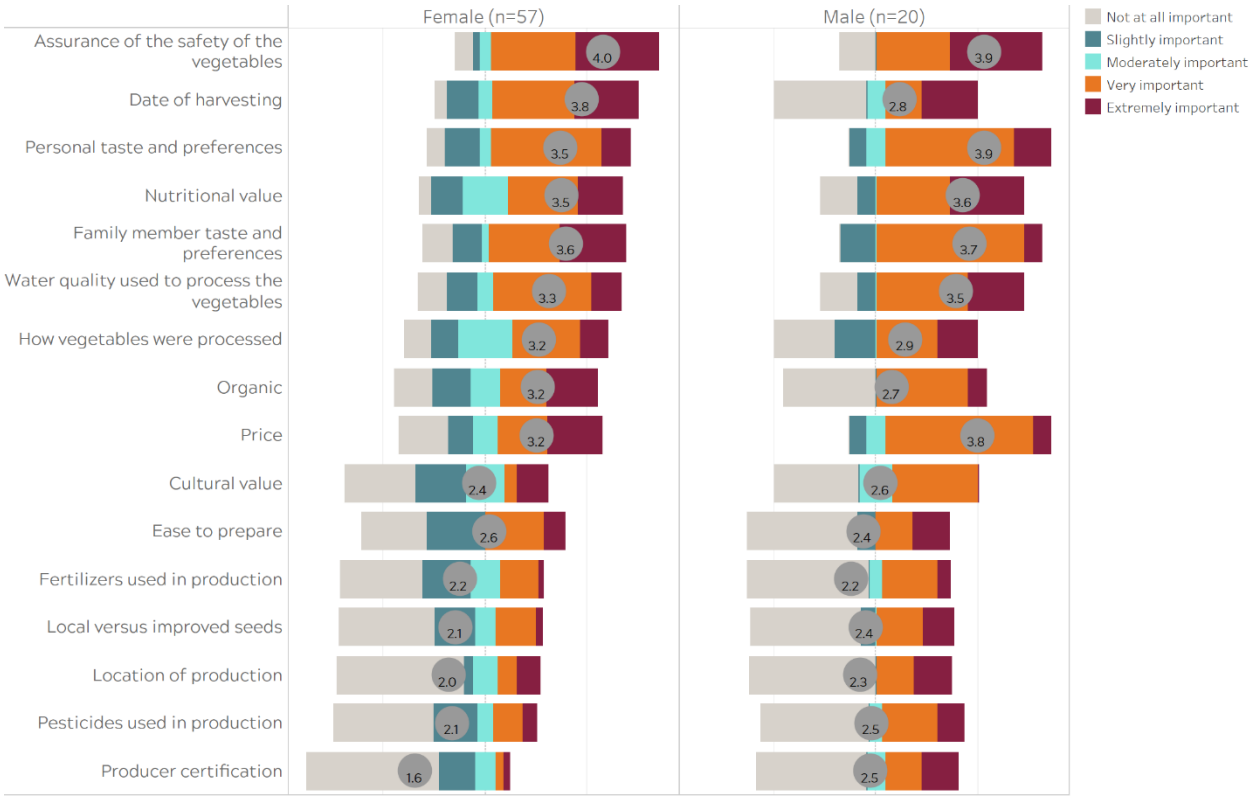
According to the United States Drug Administration (USDA) dietary recommendations, individuals should consume at least 100 g of uncooked vegetables as a single serving. Based on the number of members in a household, the average grams per week per person purchased does not meet the recommendation for even a single serving of vegetables (Table 3). According to consumers, more money (68%), more information on how the vegetables were produced (24%), and guidance on how to prepare the vegetables (17%) would increase the volume of AIVs purchased weekly. Roughly 15% of consumers explained they would need more people in their household to increase their volume of purchase. This suggests that household AIV consumption has reached saturation. Other factors that consumers indicated would increase the level of consumption include improved quality of AIVs (5%), more information on the nutritional value of AIVs (3%), the volume of available vegetables (1%), information on ways to preserve the vegetables (4%), and accessibility (1%).

Table 3. Consumption of AIVs in grams per person in the household

Variety	Grams per Person Per Week	Grams per Person per Day
Cowpeas	531 g	75 g
Spider Plant	508 g	73 g
African Black Nightshade	476 g	68 g
Jute Mallow	406 g	58 g
Amaranth	185 g	26 g
Spinach	152 g	22 g
Pumpkin Leaves	134 g	19 g
Ethiopian Kale	48 g	7 g

Figure 10 presents the distribution of importance for various AIV characteristics to consumers. Bar segments to the right of center aggregate the responses indicating that the characteristic is important when making a purchase decision; to the left of center are less favorable responses.

Figure 10. Preference for AIV characteristics



One of the most important characteristics to consumers is the assurance of the safety of the vegetables. Freshness, personal/family tastes and preferences, and the nutritional value of the vegetables are important to consumers. Price is also considered important, though on average it may be slightly more important to men (3.8) than women (3.2)(p-value: 0.11). Consumers indicate that the use of pesticides and fertilizers is not important in their purchasing decision even though the assurance of vegetable safety is very important. The cultural value of AIVs, ease to prepare, type of seed, location of production, and producer certification are of less importance to consumers.

While price is important to customers, some characteristics would lead them to pay more for AIVs. Personal taste and preferences and organic vegetables would incentivize 17% of consumers to pay more for AIVs. Assurance of the safety of the vegetables would increase willingness to pay among 13% of consumers. Other factors that would lead to increased willingness to pay among a small proportion of consumers (5-12%) include the date of harvesting, type of seed (local versus certified), nutritional value, fertilizers and pesticides used in production, knowledge of how the vegetables were processed, and the ease to prepare. The cultural value and the location of production are of little value to consumers.

Risks for Value Chain Actors

AIV value chain actors tend to face substantial risk due to thin profit margins and other factors. For example, almost all actors cite experiencing climate and/or weather-based risks (Figure 11). This stems from the fact that AIVs are highly sensitive to the ecological environment. Risks also tend to be gendered. For example, a greater proportion of male producers cite COVID-19 as a risk compared to female producers (p-value: 0.03).[2] Contrastingly, 15% of female respondents cite gender risks compared to only 8% of men. Other issues included finance-related risks such as high-interest rates or lack of access to capital.

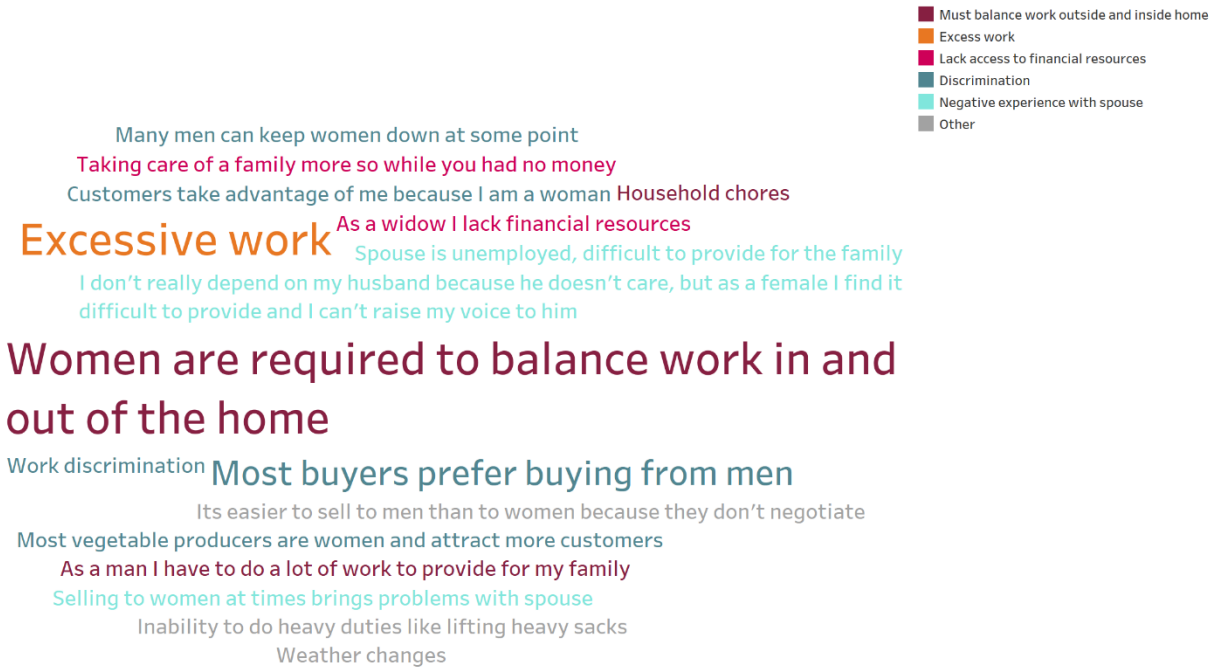
Figure 11. Risks faced by respondents

The highest proportion of female actors that report gender-based risks are retailers (26%). The difficulty that retailers experience in starting their business is one of the leading contributors to this perception. Thirty percent of female retailers indicate that it is harder for women to become retailers than men due to difficulty in accessing credit and the extent of household responsibilities (i.e., chores, childcare). The balance of work is a commonly cited challenge across other value chain actors, both male and female (Figure 12). One man indicated he had a lot to do to be able to sustain his family. Women face excessive work, needing to balance work in the household with work on the farm or in the market. Various types of gender-based discrimination were commonly reported. For example, customers appear to prefer to buy from men, because women negotiate too much. This may be

[2] There is no statistically significant difference between the proportion of female and male retailers that cited COVID-19 as a risk.

because women feel they may be taken advantage of in a transaction. Spousal dynamics affect both men and women. For men, selling to female customers may cause problems with their spouses. Contrastingly, some women do not believe they can advocate for their interests with their husbands. For example, one respondent said, "since I am a female and I don't really depend on my husband [to produce AIVs] who also doesn't care, I find it difficult to provide and I can't raise my voice to him."

Figure 12. Gender risks faced by respondents



Transactional Efficiency and Pain Points

AIV prices fluctuate during the season based on the volume of supply and demand. Table 4 presents the average AIV sale price per kilogram (kg) at each stage of the value chain. There is some discrepancy in the sale prices reported by producers and middle people. Based on prevailing market knowledge, the price reported by middle people is more accurate. Producers are usually paid between 50 and 60 KES per kilogram of raw AIVs (~US$0.46).[3]

Middle people earn between 26 and 40 KES per kg, while retailers earn between 126 and 339 KES per kg, depending on the variety. Sunhemp, amaranth, cowpeas, spider plant, and jute mallow offer producers the best prices. Amaranth and cowpeas are the most profitable varieties for middle people, while jute mallow and Ethiopian kale are the most profitable varieties for retailers.

[3] For comparison, the producer price for lettuces and leafy grains was $1.03 per kg in 2019 in the US.

Table 4. Sale price of AIVs along the value chain

	Producer	Middle Person	Middle Person	Retailer
	Producer Reported	Middle Person Reported	Middle Person Reported	Retailer Reported
Amaranth	110 (0, 5000)	56 (33, 133)	93 (67, 200)	234 (20, 2000)
Cowpeas	315 (0, 20,000)	56 (33, 133)	96 (67, 222)	222 (20, 2000)
African Black Nightshade	135 (1, 5,000)	50 (7, 67)	89 (67, 200)	273 (20, 2000)
Spider Plant	66 (2, 400)	56 (33, 133)	82 (67, 133)	102 (20, 200)
Jute Mallow	111 (1, 4,000)	56 (33, 133)	89 *67, 200)	306 (20, 2000)
Ethiopian Kale	36 (4, 210)	53 (33, 67)	84 (67, 133)	423 (67, 2000)
Sun Hemp	110 (4, 2,128)	67 (33, 133)	56 (7, 133)	182 (83, 280)

Note: Minimum and maximum in parentheses

Producers' lack of awareness of AIV sale prices likely stems from operational inefficiency rather than exploitation by middle people or retailers. One indicator of this is the lack of record-keeping throughout the value chain. The majority of producers (78%) and retailers (94%), and all of middle people (100%) do not keep any records. The producers that do keep records track sales, the planting date, and the harvesting date. Retailers tend to track who they purchased from, purchases and sales, and unsold AIVs/waste. However, there were no value chain actors tracking price per kg per AIV variety over time. Among those who do keep records, nearly 100% confirm that it helps to improve their income. Those who do not keep records suspect that it may help them, but require training to implement record-keeping in their operations and learn to use records to increase income. Another indicator of operational inefficiency is the lack of price standardization. Weights are not used in the sale price setting procedure. At all stages of the value chain, AIVs are priced based on bundles. Each actor subsequently splits the bundle and reprices it. This lack of standardization may be contributing to a loss of profit for all actors.

The FGDs confirmed that the lack of organization of actors' respective activities makes it difficult to coordinate vertically or horizontally along the value chain. Each value chain actor was asked what the actors they interact with could be doing better in their respective roles. Table 5 summarizes the responses. Despite producers generally indicating they trust middle people when ranking on a Likert scale (Figure 14), they also indicate they are looking for more trustworthiness in their interactions with them.

Table 5. Recommendations for improving quality of processes

	Producer	Middle Person	Retailer
Producer		Be trustworthy Assist in marketing Avoid debts and pay on the spot Pay better prices	Increase demand and consumption
Trader	Increase production and bundle size Use a scale to standardize the weight Prepare and pack vegetables in the evening Be more aware of the seasonal demand for vegetables		Come to the market to pick up AIVs Reduce bargaining power Buy vegetables in the morning Increase quantity purchase Fully specialize to reduce competition in the market Use open carriers to avoid compression of the vegetables
Retailer	Use irrigation to ensure a consistent supply of AIVs Change production practices to improve the quality of the vegetables Minimize pesticide residues on the vegetables	Have different varieties available, especially those demanded by the consumer Provide full information on the AIVs	
Consumer	Minimize pesticide residues		Ensure consistently availability of desired varieties Increase the size of the bundle Use hygienic practices Be willing to sell on credit Ensure freshness Use consistent measuring for selling Sell vegetables in a raised ground container to avoid contamination and dust Wash vegetables in clean water

Two consistent pain points are the pricing of the vegetables and the size of the bundle sold; each actor is looking for competitive value for money. Meanwhile, consumers want retailers to be willing to sell on credit. Traders, retailers, and consumers are looking for an improvement in the quality of vegetables, including minimizing pesticide residues. Retailers desired full information on the AIVs. There is also a desire for popular varieties of AIVs to be more consistently available. This reflects the sentiment of Figure 7 which reveals a discrepancy between the varieties sold versus the varieties demanded and a potential lack of retailer awareness of the desired varieties. Table 5 suggests that this mismatch occurs because producers are supplying less demanded varieties to the market; however, producers' request for assistance in marketing from middle people may indicate they lack the market information they need to meet demand.

FGDs helped to further investigate the pain points, opportunities, positive trends, and needs of each value chain actor group (Table 1). The most commonly cited negative trends and headaches are related to the weather and climate, pests and disease, lack of a ready market, lack of information regarding the market and/or AIVs, and price instability. Women face the risk that men will demand the income they earn from the sale of AIVs, even though they do not participate in the production, harvesting, or marketing process. Theft and lack of security are also concerning for value chain actors, particularly retailers.

There is a hopeful sense that with improved vertical coordination and training in pest and disease management, business operations, productivity, and nutritional benefits, the market for AIVs could be developed. Value chain actors are very keen to explore these opportunities. There also appears to be a consensus that there is ready demand for AIVs, but that there is a need to improve the functionality of the value chain to consistently meet that demand. To a lesser extent, there is interest in finding ways to preserve the vegetables to reduce post-harvest losses and maximize profit margins.

Table 6. Pain points, opportunities, and needs among AIV value chain actors

	Negative Trends	Positive Trends	Headaches	Opportunities	Hopes	Fears	Needs
Producers – Male	No training on pest and disease management Lack of information Loans need collateral Price fluctuations	Demand for AIVs Availability with rain Smartphones and technology Training programs Linkage to markets for selling AIVs Fertilizer subsidies Men are getting more involved in AIV farming Groups in farming and marketing Post-harvest drying More people demand AIVs	Pests and disease Marketing Poor soil health Lack of access to capital/credit Purchases of farm equipment Lack of enough capital to fund How to make money on cash crop after sugar cane failure	Training Use the training to raise issues they encounter Ready market opportunities Guidance on planting practices Produce certified seeds	Receive training on conservation agriculture To get money from AIV production Training on pest and disease management Micro-financing Using chisel plow Receive training on soft loans & soil testing Predictable weather	To incur losses Change in rain pattern and weather Drought Fall armyworm Risk of the phone	Finance and credit Soil testing Assistance with pest and disease management Training on borrowing and financial management Need cheap loans Training on cheapest technology
Producers – Female	Some people fail to pay the agreed-upon price Fertilizers are expensive Lack of market Farm work is considered women's work High transportation costs Excess rains destroy AIV crops No production during the dry season Women have access but lack control – no decision-making ability	Availability of manure Making own seeds The market is near Demand for AIVs Availability with the rain Continuous production of AIVs throughout the year is possible	There is little money in January Getting AIVs to the market Surplus production during the rainy season No access to market information	Training in farmers groups Markets for AIVs and their seeds Grow in scale of production if markets can be identified Believe there is a ready market	Access to information Improve livelihood Rainfall Availability of manure High market prices for the produce Direct linkage to market Increase income margins Increase scale of production	Men may ask for the income from AIV sales Lack of market Increased supplies during the rainy season Debts aren't repaid Uncertainties on weather Invasion by pest and disease Imbalance of supply and demand Will not be able to sell	Accessing steady markets Training on pesticide use Financial support Farm inputs Direct access to physical markets and market information

	Negative Trends	Positive Trends	Headaches	Opportunities	Hopes	Fears	Needs
Middle People - Men	Rainfall patterns are changing Pests and disease	Growing population Increasing demand for vegetables	Poor pricing High expense during the rainy season Shortage of water	Ready market available Provide training on credit opportunities Tourism increases the demand for food	Hope for an improved method of preserving and management of post-harvest losses	Lack of market for vegetables Not sure about trusting everyone in the value chain	Improve infrastructure Learn how to save Linkage to markets Training on other sources of income AIV driers
Retailers – Female	Lack of market Built toilets in front of the market Thieves Lack of AIVs during the dry season If traders lack money, they only buy small quantities from producers	Emerging technology Selling AIVs improves livelihoods Cash can be earned quickly from selling AIVs	AIV wastage due to lack of market No customers Lacking AIVs to sell	Customers from Nairobi buy when traveling If not able to sell, middle people may not require payment Can resell to other retailers Trustworthy customers pay debts Communication with customers	Educating children Improving living standards Availability of customers Availability of quality AIVs Availability of all varieties	If men know women have money, they won't provide If growing AIVs they will be stolen Theft by neighboring retailers	Capital Umbrella to cover AIVs while selling Training on where to sell produce Marketing opportunities A phone to market AIVs Sell/grow other types of crops Training on planting AIVs
Consumers - Male	AIV price fluctuation, especially increase in prices	Different varieties of AIVs are available Emerging technology Marketing strategies	Seeds fail to germinate Lack of money to purchase AIVs Pests and disease	With enough money would produce their AIVs To interact with new buyers using smartphones	Get certified seeds and plant AIVs Use an app to have linkage with sellers Get information on planting during the dry season Reduce buying and increase growing New technology	Safety and source of the AIVs Where to source the money to buy AIVs Heavy reliance on the market to get food To miss meals during the day	Information on the safety of AIVs Training programs on nutrition Plenty of vegetables in the market Learn how to preserve AIVs

	Negative Trends	Positive Trends	Headaches	Opportunities	Hopes	Fears	Needs
Consumers - Female	Fluctuations in market prices of different vegetables Packaging of lower quality AIVs	Different varieties of AIVs are available in the market	Seeds fail to germinate High prices during the dry season	With enough money, would produce their own AIVs		Theft/security Diseases Packaged AIVs are not available Hygiene of vegetables Buying old AIVs	Fresh vegetables More packaged AIVs Young & tender vegetables Information on nutrition

Transactional Trust

Respondents indicate that in general, they trust people, except for consumers, though they feel that they cannot rely on people and must be cautious when dealing with strangers (Figure 13). Further research into the way actors define trust and reliability is needed as the conflicting results are hard to interpret.

Figure 13. Level of trust in general

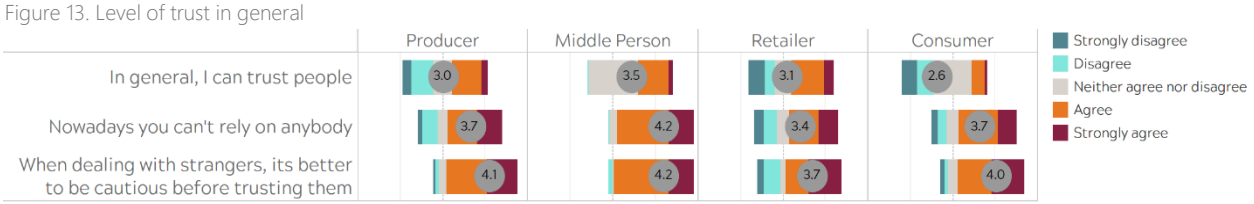


Figure 14 indicates that value chain actors tend to trust one another, though consumers are less trusting of middle people. Middle people demonstrate a high degree of trust towards middle people. Retailers tend not to trust creditors, large companies, or the military. The only group of actors that have trust in the military is middle people.

Figure 14. Trust in other value chain actors and business enabling environment

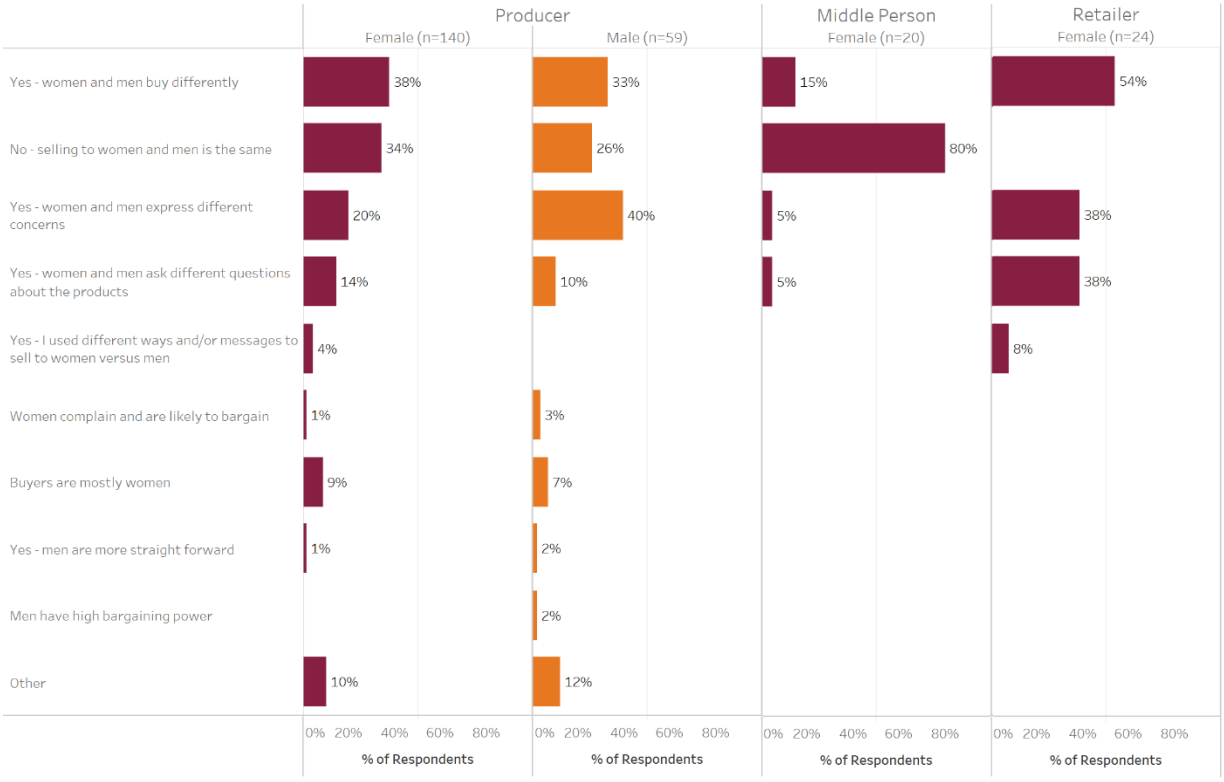
According to producers and middle people, the price or the quantity sold may differ from the original agreement due to changes in the market (12%), fluctuations in supply (50%), or an increase in transportation costs (4%). There is conflicting information as to whether these changes affect the trust between actors. The FGDs indicate that this is a pain point for female producers, but the questionnaire results highlight that middle people need to be more trustworthy of producers, retailers, and consumers. However, producers also indicate that they generally feel that their buyers treat them fairly (66%). There is evidence that may indicate a greater proportion of male producers (57%) feel they are treated fairly compared to female producers (50%); however, this difference is not statistically significant (p-value: 0.367).

Some producers feel they are being cheated on the price of AIVs, while others recognize the pricing inconsistencies across markets. For example, one respondent said, "if a buyer is from Mumias, they will buy at a higher price, but if a buyer is from Buchipi they will buy at a very low price." Producers also cite that buyers either complain or bargain too intensively about quantity of vegetables sold at certain prices or overall volumes.

Gendered Transaction Perceptions

The gendered perceptions of transacting were investigated between buyers and sellers to assess if women face difficulty in conducting their respective activities as a result of their gender (). The majority of buyers (i.e., traders, retailers) do not see a difference between buying from men and women (75%). Figure 15 reveals that 34% of female producers, 26% of male producers, and 80% of

Figure 15. Gendered transaction perceptions



middle people do not find a difference in selling AIVs to men versus women. Of the 66% that do find there is a difference, between 15 and 54% believe that there are just fundamental differences between the way men and women buy. Between 5 and 40% of sellers find that men and women raise different concerns. Some sellers note that it is difficult to assess the difference because men very rarely buy vegetables (7-9%). One enumerator observed in the immersive research that men tend to accept the price as given for the AIVs while women negotiate to try to get a greater quantity from the price. This is reflected in Figure 15, respondents citing that women complain and are likely to bargain (1-3%) or that men are more straightforward (1-2%).

Flow of Information in the AIV Value Chain

Understanding the flow of information about vegetables and the way they were produced, transported, or processed and information about consumer demand helps to identify underlying causes of inefficiencies within the value chain such as an insufficient supply of demanded varieties. Figure 16 depicts the types of information that respondents report they receive from various value chain actors. The color of the node indicates the value chain actor from whom the information originates. The actor receiving the information is the center node. The size of the node represents the number of participants reporting that the information is shared.

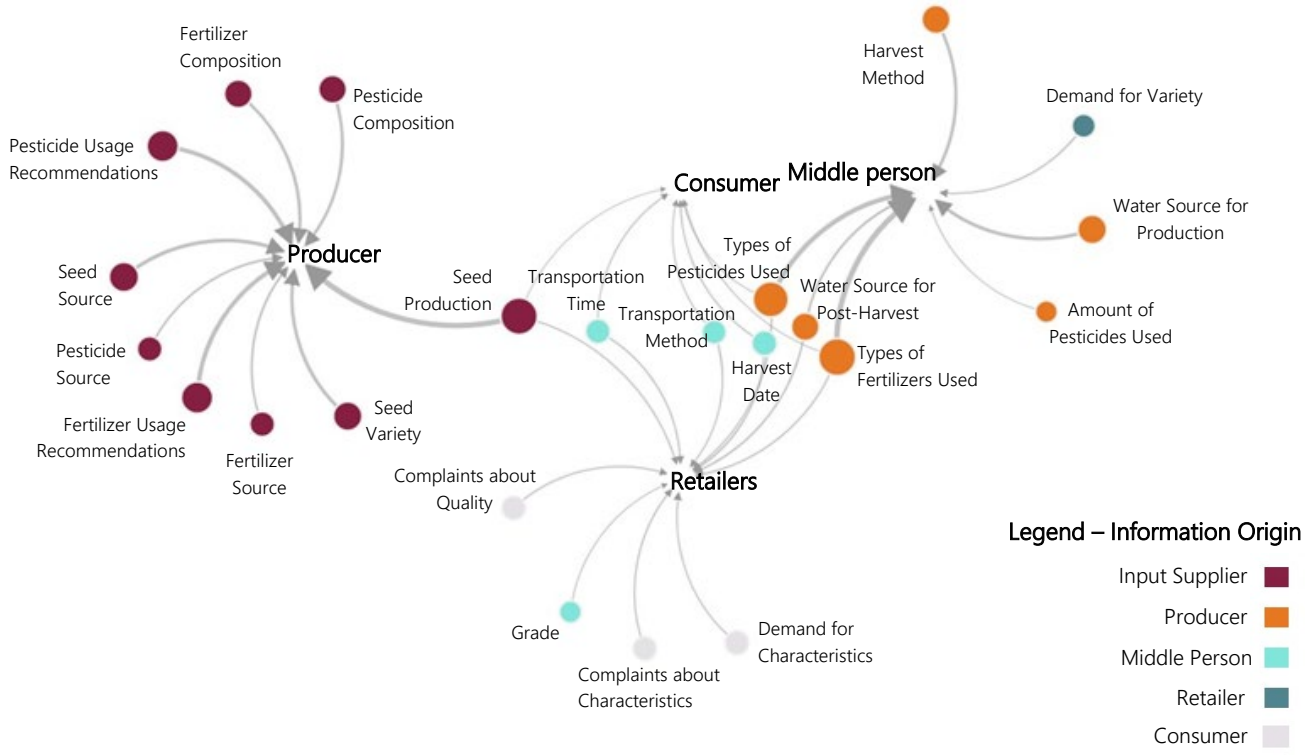
The maroon nodes represent information originating from input suppliers that are shared with producers, middle people, retailers, and consumers (seed variety). Seed variety and pesticide and fertilizer usage recommendations are the most frequently shared information. Seed variety (i.e., local versus certified) is shared with consumers as well as retailers. To a lesser extent, input providers share information about the pesticide and fertilizer source and composition.

The orange nodes represent information originating from producers, as reported in the value chain questionnaire. The most common information that producers share with middle people is the types of pesticides and fertilizers used. This information is also shared with retailers and consumers.

As indicated by the light turquoise nodes, middle people claim to share the harvest date with retailers and consumers; however, this is information that should originate from the producers, but it is not indicated that producers provide these details to middle people. To a limited extent, middle people share information on the length of time vegetables spend in transportation, the type of transportation used, and the grade of the vegetables with retailers which in turn are shared with consumers.

The network graph in Figure 16 identifies discrepancies in knowledge transfer along the value chain. The color of the node indicates the actor with whom the information originates. For example, seed variety information originates with input suppliers and is reported to be provided to producers, retailers, and consumers but not to middle people. The visualization of the information sharing network reveals some discrepancies. For example, the harvest date is reportedly provided to the retailer by the middle person, but producers do not report sharing this information with the middle person.

Figure 16. Information transfer between value chain actors



Mismatch of Supply and Demand

Poor transmission of information along the value chain is one of the root causes of the mismatch of supply and demand in the market. Producers are not aware of the volume of specific AIV varieties demanded in the market or the vegetable characteristics that are desired by the consumer. This creates the opportunity for middle people and retailers to take advantage of lower prices to suppress prices. It also results in revenue loss, not only for producers but all actors along the value chain.

Consumer Access to Information

Consumers report having access to very little information about AIVs at the point of sale. Approximately 13% of consumers indicate that they are able to find out the date the vegetables were harvested. Other than that, less than 4% of

Box 2. Immersive research experience – market mismatch

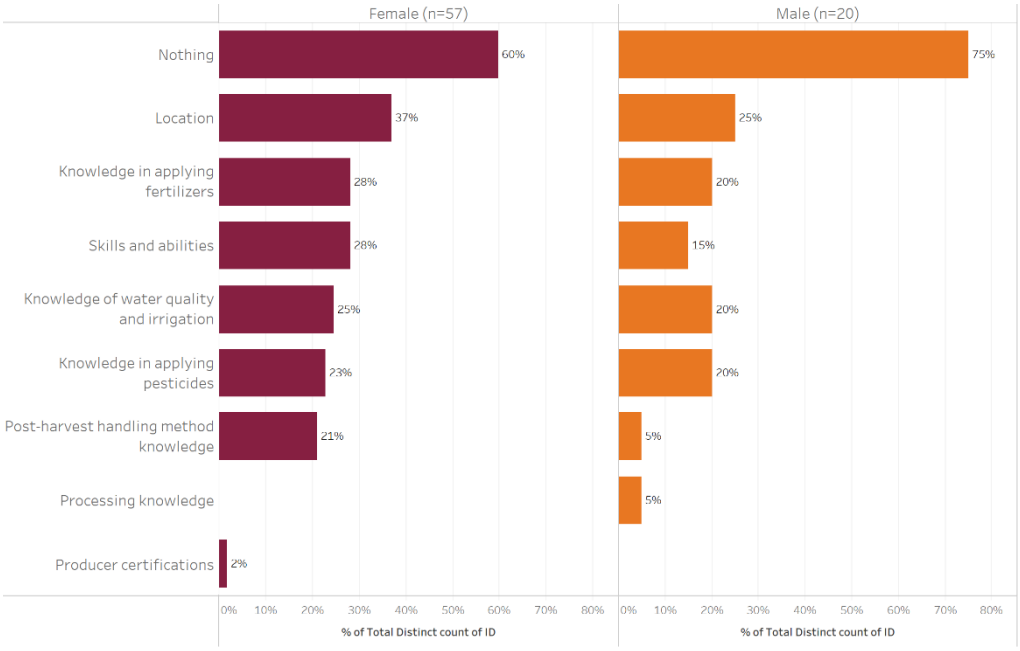
Evidence of Market Misinformation Used to Suppress Producer Prices

In February 2021, two Egerton University students walked a mile in the shoes of an AIV producer to conduct immersive research. Their goal was to understand the realities of producing and marketing AIVs from the perspective of an AIV farmer. Each student understood two different market conditions based on the information communicated to the producer. In one household – the trader was desperate for more vegetables so they could meet the demand of the market. In the other household – the trader could not pay a high price as there was no demand in the market. The difference? The former producer spent time in the market herself, while the other producer did not leave his homestead very often. This anecdote indicates that a producer's access to market information may be of central importance to price negotiation.

consumers indicate that they can obtain information on characteristics that would influence their willingness to pay for vegetables such as the use of chemical fertilizers or pesticides and the water quality used to process the vegetables.

Transfer of information about the actors, especially producers, is largely non-existent. Approximately 75% of male shoppers and 60% of female shoppers do not know anything about the producers who grew the AIVs they purchase in the market (Figure 17).[4] Of the 35% of consumers (n=28) that do know something about producers, they most often know where the producer is located, if they have some knowledge about apply fertilizers, their skills and abilities, and knowledge of water quality and irrigation. This awareness and access to information are usually because the consumer knows the producer of the vegetables they are buying.

Figure 17. Consumer knowledge of producers



Technology Usage

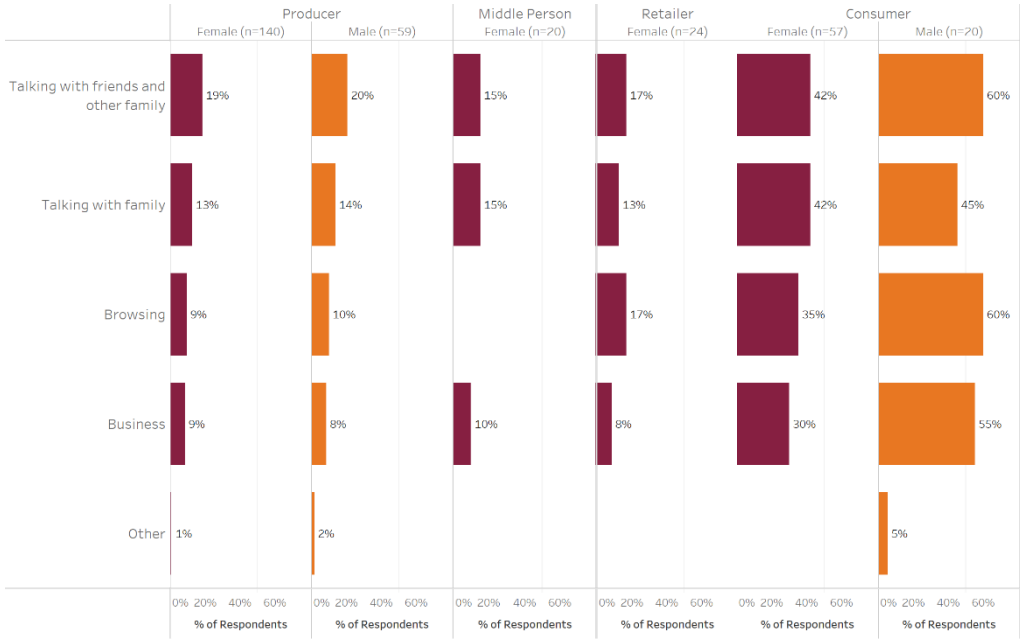
The success of digital solutions for value chain inefficiencies requires at minimum that actors are able to buy and use a smartphone. Between 25 and 30% of female value chain actors and 50% of male value chain actors have previously used a smartphone (Figure 18). More than 50% of consumers have used a smartphone previously (53% - women; 70% - men) (p-value: 0.169). Of those who had previously used a smartphone, ownership was less than 20% for female value chain actors, 25% for male producers, and 0% for male retailers. Among consumers, 44% of women currently own a smartphone compared to 70% of men (p-value: 0.038).

[4] The difference is not statistically significant (p-value: 0.229).

Figure 18. Smartphone ownership by value chain actor and gender

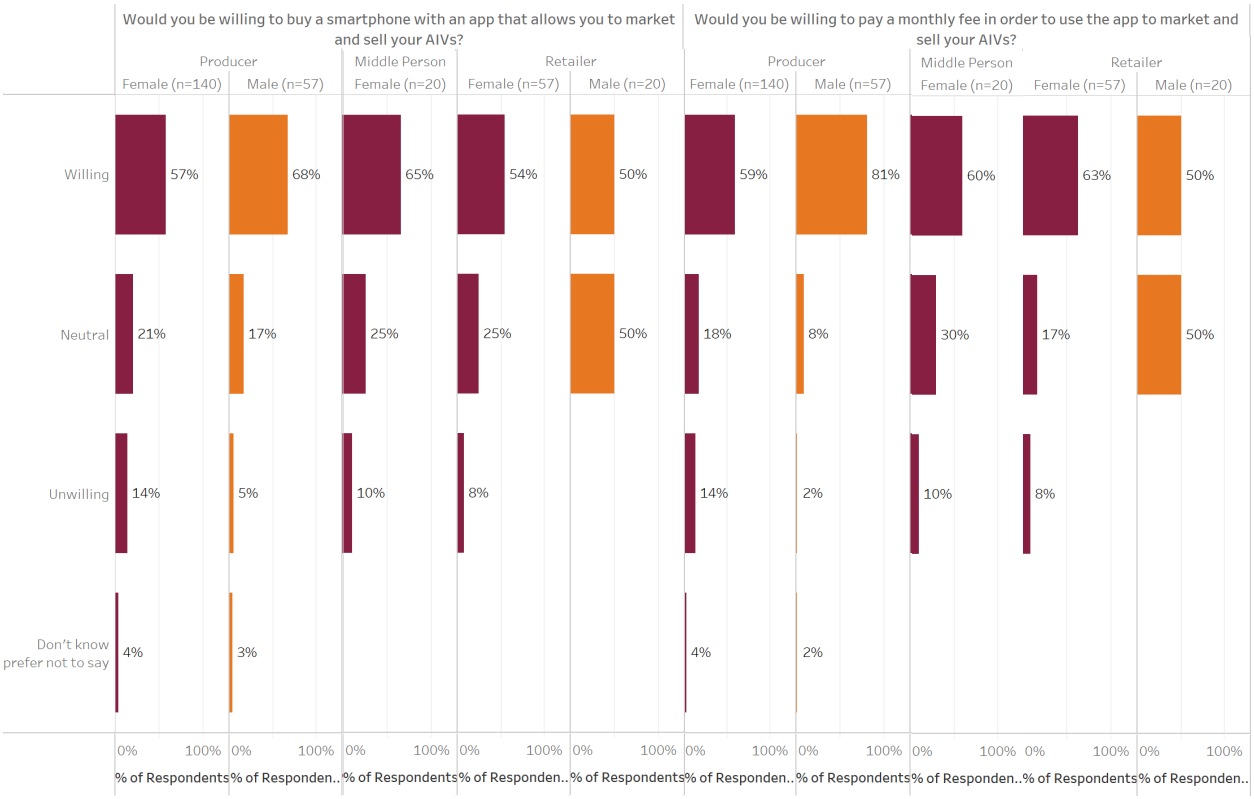
Phones are most often used for talking with friends and family outside the household and family within the household (Figure 19). Business use for the phone is limited to 6% of producers with a phone and less than 1% for middle people and retailers. Consumers are more likely to be using their phones for business (10%). Only 1% of middle people or traders have ever used mobile technology to engage in the marketing of agricultural products.

Figure 19. Smartphone uses by value chain actor type and gender



The majority of respondents were aware that mobile technology can be used to market agricultural products (75%); however, only 14% of respondents have ever used smartphones to market their AIVs. There is significant interest among all value chain actors to use digital solutions to improve the marketing of their AIVs. Almost all producers, middle people, and retailers are willing to adopt digital marketing of their AIVs (90%). Furthermore, between 60 and 70% of producers, middle people, and retailers are willing to both buy a smartphone and pay a small monthly fee to use a digital platform to market their AIVs. Among those that currently own a smartphone or usually do but don't have one at the moment, 75% regularly pay for data. The majority of respondents (65%) spend more than 50 shillings per week on data. Willingness to pay for this expense is critical for using digital solutions in agri-food value chains.

Figure 20. Willingness to pay for smartphones and data



COVID-19 and Technology Concerns

The COVID-19 pandemic has had a profound impact on the local economy. In addition to depressed market prices and fluctuations in the availability of nutritious food, the economic downturn has resulted in an increase in borrowing among business owners to sustain operations. As a result, some retailers and other business actors are not interested in being paid with m-PESA and other mobile money platforms, as any amount transferred to them while there is a credit against their account goes immediately to paying back the principal amount. Thus, many actors have preferred to operate with cash, despite the risks of transmission. There are also other concerns regarding the use of digital

solutions. One of the retailers shared that she had previously taken part in a project involving smartphones and mobile technology for saving; however, the app she used was hacked and she lost money. While she was interested in the project we were proposing, there was reluctance for fear of losing again. This is one potential area that BCT may introduce peace of mind and trust for value chain actors by increasing the security of transactions.

Food Security and Socio-Economic Status

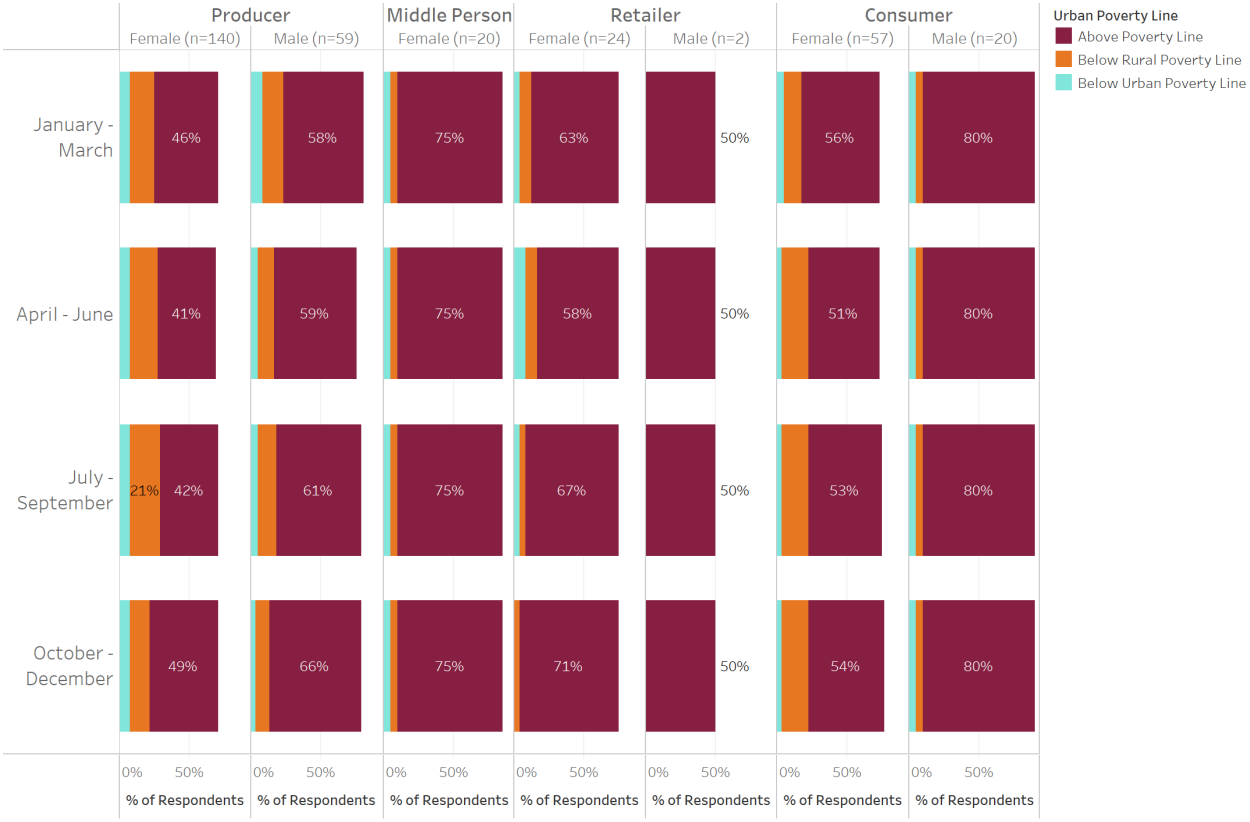
One of the main objectives of this project is to contribute to the food security of small-scale farmers and other value chain actors by improving the income earned from the sale of AIVs and increasing the demand for and availability of AIVs in Kakamega. Figure 21 breaks down the average income of each value chain actor by quarter. As expected, producers realize the lowest income throughout the year. Retailers on average earn the highest income monthly followed by consumers.

Figure 21. Average monthly income by quarter, activity, and value chain actor

	Producer	Middle Person	Retailer	Consumer
January-March	17,428	33,724	35,400	29,648
April-June	19,074	26,082	37,053	29,545
July-September	18,697	25,506	34,600	29,062
October-December	21,525	27,106	38,684	29,721

According to the World Bank, the monthly poverty line is 3,252 and 5,995 KES per person per month (~US$30 - $55.61) (World Bank 2020). The majority of middle people and retailers have an average monthly income above the urban poverty line across all four quarters of the year, based on the per person estimation of declared household members. Approximately 25% of both male and female producers have an average monthly income below the rural poverty line. Other than the first quarter of the year, a greater proportion of male producers have incomes above the poverty line than female producers (p-value: 0.12; 0.02; 0.01; 0.028). A larger proportion of male consumers also have an income above the poverty line than female producers (p-values: 0.056; 0.02; 0.03; 0.04). Producers and consumers have a higher proportion of respondents below the poverty line than middle people or retailers.

Figure 22. Respondent income according to poverty lines



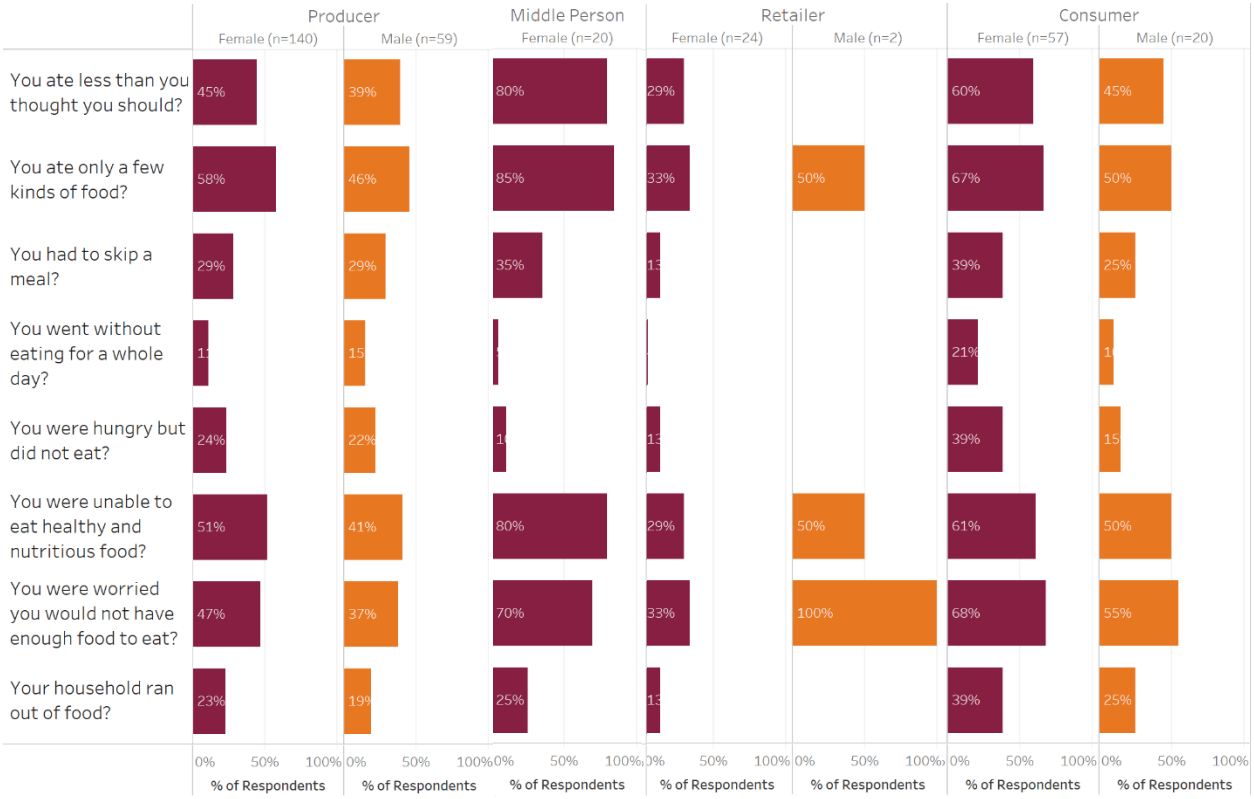
Food security was measured in terms of the experience of the household in accessing food due to resource constraints and the dietary quality of the respondent, the respondent's spouse, and any infants in the household. The Food Insecurity Experience Scale (FIES) uses self-reported food-related behaviors and experiences associated with difficulties in accessing food due to resource constraints in the previous 30-day period (FAO 2018).

The most common experiences for all value chain actors were eating less than they thought they needed, only eating a few kinds of food, not being able to eat healthy and nutritious foods, and being worried they would not have enough food to eat (Figure 23). A larger proportion of middle people experience these four situations compared to producers, retailers, and consumers (p-value <0.01). Importantly, this demonstrates the importance of increasing access to nutritious foods and improving income to increase individuals' confidence that they will have the resources to buy enough food for themselves and their families. The proportion of consumers reporting having gone a whole day without food is higher than AIV value chain actors (18%), followed closely by producers (12%).

Figure 23 reveals that a greater proportion of women experience barriers to accessing the food they need than their male counterparts, however, the difference is not statistically significant. Among retailers, a greater proportion of men may be worried that they would not have enough to eat (100%)

compared to women (33%); however, the difference is also not statistically significant due to the low sample size of men.

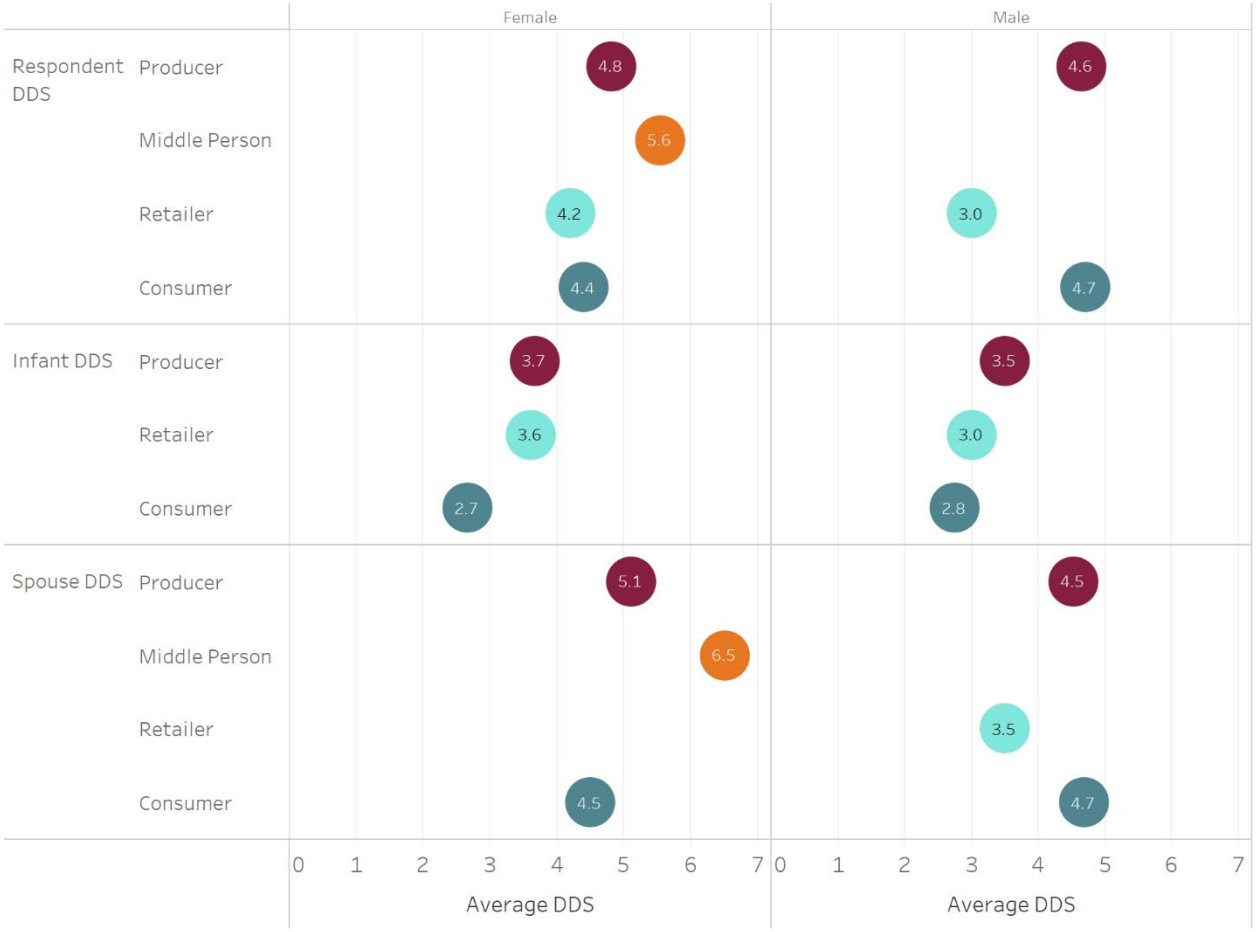
Figure 23. Food insecurity experience by value chain actor and gender



Food security was also assessed in terms of dietary quality. The Diet Diversity Score (DDS) was used as a proxy for dietary quality and was calculated at the individual level (Swindale and Bilinsky 2006). Respondents were asked to report their consumption of the following food groups in the previous 24-hour period: grains, roots and tubers, legumes and nuts, dairy products, flesh foods, seafood, eggs, vitamin A rich fruits, vitamin A rich vegetables, dark leafy green vegetables, other fruits, and other vegetables. For infants, breastmilk was also included in this list.

The average DDS score for all value chain actors is between 4 and 5 (Figure 23). This is comparable to other surveys of producers in Kenya (Muthini, Nzuma, and Nyikal 2020). Female retailers and producers may have a slightly higher average DDS than their male counterparts; however, the difference is not statistically significant. Female respondents on average report a higher DDS for their spouse than themselves. Male retailers are the only actor group that reports a better DDS for their spouse than their own on average. While the DDS cannot measure nutritional adequacy, usually a score of 5 is considered to be a minimally acceptable quality of diet. While Figure 23 suggests that the spouses of middle people (all men) exceed the minimum score of 5, this category only has a sample size of two so further investigation is needed.

Figure 24. DDS by value chain actor and gender



Addressing food security necessitates increasing the number of food groups that are consumed each day. Figure 25 breaks down the consumption of food groups by participants, including fat consumption. The majority of value chain actors had eaten grains/carbohydrates, leafy vegetables, dairy products, and sugar in the previous 24-hour period. This breakdown suggests that vegetable consumption is common; however, the nutritional benefits have not been realized from AIVs. The food recall does not measure the quantity consumed or how the foods were prepared; this has important implications for the nutritional impact that needs to be further investigated. Increasing diet diversity will require increasing the affordability and accessibility to fruit, legumes and nuts, eggs, and high-quality protein.

Figure 25. Food group consumption by actor

Conclusion

This PVCA demonstrates the biggest pain points that need to be addressed are the lack of coordination throughout the value chain, assurance of vegetable safety for consumers, improved transmission of information through the value chain, standardization of grading and pricing, improving the market power of women, and technical assistance for producers in pest and disease management and production practices to improve yield. Prior to the value chain analysis, it was expected that AgUnity's BCT-based digital platform would improve the functionality of AIV value chains primarily by increasing trust between value chain actors and by improving the flow of information through the value chain. While there are anecdotal incidents of middle people cheating producers, it is of greater importance to all value chain actors that knowledge transfer processes are improved.

While smartphone ownership is currently low in Kakamega, there is ample interest in obtaining a smartphone to access digital solutions for the agri-food value chain. Actors are also willing to pay a small subscription fee for utilizing a smartphone app that will help address key pain points. BCT is well suited to addressing some of the most critical pain points, but not all. For example, the nutritional

information of the vegetables is not necessarily well suited to the blockchain, but with properly certified and monitored information, the AgUnity platform can be used to track organic vegetables from farm to market. Integration of the platform with other technology such as Internet of Things sensors could provide consumers information on water quality used to clean the vegetables. The secured transactions created on the blockchain can also provide all value chain actors reliable pricing information when integrated with record-keeping features to improve transparency and produce market power. The secure wallet used to record transactions may also help women to retain control over revenues earned from the sale of AIVs.

The findings from this PVCA reveal that BCT will not provide a magic bullet to address the constraints within the AIV value chain; however, when integrated with other services (i.e., record keeping) and training, there is significant potential for a distributed ledger to improve vertical coordination between actors and increase the flow of information along the value chain. Further investigation into the means for certifying information stored on the blockchain will be undertaken in the next phase of this research, but preliminary meetings with MoALF extension agents have revealed the potential for collaboration with existing services and support to producers as a means by which this could be conducted. Further research is also needed on how the AgUnity BCT-based platform will help women improve their market position and decision-making power, both in the household and in business operations.

BCT offers important solutions for increasing AIV sales and income-earning opportunities, the availability of desired AIV varieties, and demand for the leafy greens by offering characteristics valued by the consumer. Thus, there is potential for this technology to contribute to improvements in food security in Kakamega and other nutritionally important agri-food value chains.

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