POSTHARVEST HANDLING SYSTEMS FOR FRESH FRUITS AND VEGETABLES IN SUB-SAHARAN AFRICA AND POTENTIAL ENHANCEMENT BY THE AID FOR TRADE INITIATIVE

by

SARA ASHLEY SPARKS

(Under the Direction of Robert L. Shewfelt)

ABSTRACT

To address food insecurity and high levels of postharvest loss in developing countries the postharvest handling systems in sub-Saharan Africa were characterized using a systems approach. The Commodity Systems Assessment Methodology (CSAM) and analysis of interview transcripts were used to develop six models representing the postharvest handling system of four crops. Completion of the models identified areas where postharvest technologies could be most effective in reducing postharvest loss in the food system. The potential of Aid for Trade to provide support for developing countries was explored. Allocations have the potential to provide needed linkages within the postharvest handling system to reduce loss. Investments in the economy, trade capacity, and infrastructure of developing countries could improve the efficiency and reduce observed postharvest loss.

INDEX WORDS: postharvest, postharvest handling, systems, fruit, vegetable, CSAM, aid for trade, developing countries

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SARA ASHLEY SPARKS

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SARA ASHLEY SPARKS

Major Professor: Robert L. Shewfelt

Committee: Jinru Chen
Maria Navarro

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
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DEDICATION

I dedicate this work to my family and friends who have supported me over the past two years. Thank you for your love and prayers.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Introduction

In 2050 the world population is expected to exceed nine billion individuals. To support a population of nine billion the current level of food production will need increase by 70% (FAO, 2009). However, the current rate of growth in the food supply and production is less than the rate of population growth. Production agriculture also consumes natural resources that are becoming increasingly scarce (Hodges *et al.*, 2011). Sub-Saharan Africa is a prime example of the negative consequences that can result from increasing land area used for agricultural production in response to expanding populations. Environmental damage has resulted from farming an increased amount of land and decreasing the fallow times for a field depleted of soil nutrients. The resulting decreases in crop yield have been significant, up to 14% in maize production alone (Paarlberg, 2010).

A significant portion of the projected growth in demand for agricultural products will come from developing nations. Trends within developing nations show an increase in fruit, vegetable, and meat consumption (Boehlji *et al.,* 1999). Inefficiencies within a food system can result in food loss. The lost food could have been eaten, sold, or traded to enhance the overall quality of life. Actions that limit food losses can increase food availability without the need for increases in production resources. Specifically in Least Developed Countries (LDCs) a reduction in food loss can support rural development and reduce poverty through the development of agribusiness (Hodges *et al.*, 2011). Reducing postharvest loss and increasing food availability

can help address the problem of feeding a growing human population. Additionally, a reduction in postharvest losses conserves natural resources and reduces the area of land involved in cultivation (Kader, 2003).

Developmental organizations have supported reducing postharvest losses since the seventies (LaGra, 1990). On a household scale, the reduction of postharvest losses could increase food availability and income due to improved marketability in sub-Saharan Africa (World Bank, 2010). Increases in income may result from reducing postharvest loss that could decrease market value of produce. Reducing postharvest losses thus results in increases in food safety, food quality, and possibly provides additional health benefits (Hodges *et al.*, 2012)

There is a need for appropriate and effective solutions to reduce postharvest loss. For the development of an effective solution, there must first be a clear definition and understanding of the problem (LaGra, 1990). Developmental plans can only be established once there is a complete understanding of the commodity system from production to distribution (Phillips and Unger, 1973).

Postharvest Background

As fresh produce is alive, biological processes impact the quality and are responsible for the deterioration process. Biological factors include rate of respiration, sprouting, rooting, changes in color, changes in flavor, changes in texture, changes in nutrition, ethylene production, water loss, and pathological deterioration. While biological processes are innate to fresh fruits and vegetables, the rate of biological processes is affected by environmental factors such as relative humidity, temperature, velocity of the air, and composition of gases in the atmosphere (Kader, 2005). Harvested produce is continually deteriorating. Recognizing proper handling practices and storage conditions is essential since decreases in quality lead to waste and

unacceptability of fresh produce to the consumer. The modification of storage conditions and handling practices to increase the quality at purchase and consumption, along with extending the shelf life of fresh items, is referred to as postharvest technology (Shewfelt and Prussia, 2009). Developments to reduce postharvest loss must have the capacity and ability to decrease the speed of deterioration (LaGra, 1990).

Environments characterized by high temperatures and low humidity can dehydrate fresh fruits and vegetables, negatively affecting weight and appearance. The temperature of environments is also critical since the chemical reactions present in harvest produce are catalytically regulated through enzymes. Enzymes can be regulated through temperature, and a 10°C increase will increase enzyme activity two to four fold. The role of temperature on the postharvest life and speed of deterioration of fresh fruits and vegetables is fundamental (LaGra 1990).

The period of time between when a vegetable is harvested in the field and when it is either processed or consumed is the postharvest stage. Postharvest handling encompasses the period of time after harvest when fruits and vegetables are living, i.e. respiring until blanching, cooking, or consumption (Shewfelt and Prussia, 2009). Activities included in a postharvest system include harvest, grading, inspection, treatments, packaging, cooling, storage, transport, delays, handlings, and agro-processing (LaGra 1990). Postharvest treatments refer to any actions or processes that are performed on fresh items including but not limited to storage, washing, grading, sorting, or transportation.

The quality of fresh fruits and vegetables includes texture, flavor, nutrition and appearance (Kitinoja and Kader, 2002). Quality can either be a measure of excellence or a lack

of defects. The term quality considers the sensory characteristics of color, texture, and flavor, as well as, characteristics like nutrition and safety (Shewfelt, 1999).

Postharvest loss can be defined as any loss that occurs after harvest and before consumption (Bourne, 1977). Postharvest loss can be the measurable loss both quantitatively and qualitatively within the postharvest system (de Lucia and Assennato, 1994). The range of postharvest loss can be from zero to a total and complete loss. The specific amount of postharvest loss is a result of climate, political situation, farmer's cultural practices, market potential, marketing policies, road infrastructure, and knowledge possessed by those involved (LaGra, 1990). Physical postharvest loss decreases market value and incomes. Reductions in quality also bring about concerns regarding food safety (Kitinoja *et al.* 2011). It is difficult to estimate an average postharvest loss because the loss is a result of many factors. The importance of the factors influencing postharvest loss vary by commodity, season, and the circumstance under which the commodities are grown, harvested, stored, and sold (Hodges *et al.*, 2011).

From the 1970s to present there has been very little improvement in postharvest loss at the farm, wholesale, and retail level even with many programs devoted to reducing postharvest loss (Kitinoja *et al.,* 2011). In developing countries, the largest postharvest loss occurs at or around the farm as a result of the variety chosen, harvesting methods, and packaging methods (World Bank, 2010). Cold chain systems and mechanization in developed countries keep postharvest loss lower on the farm than they are in LDCs.

Postharvest loss begins as early as in the field when pests attack fruits or vegetables and the presence of rains facilitates mold growth (Hodges *et al.*, 2011). Main causes of postharvest loss include lack of temperature management, rough handling, poor packaging material, and lack of education about the need to maintain quality (Kitinoja *et al.,* 2011). Additional causes of

postharvest losses in mature fruits include harvesting at over-ripe maturity or with excessive softness, loss of water, injury from improper chilling, biological compositional changes, and decay (Kitinoja and Kader, 2002). Roots and tubers are less perishable than fruits and vegetables (Hodges *et al.*, 2011).

Biological spoilage is the main cause of postharvest loss in developing countries. Biodeterioration can be the result of insects, rodents, or microorganisms (Hodges *et al.*, 2011). Fungal contamination has been identified as an important factor in postharvest losses (Saeed *et al.,* 2010). Postharvest losses can also result from using low quality seeds and materials. When there is a lack of quality material, farmers utilized whatever materials are available which could be the wrong variety or poor quality (LaGra 1990).

The goal of reducing postharvest loss can occur through growing appropriate cultivars with long postharvest life and good nutritional quality; use of integrated crop management techniques; and use of the best postharvest techniques (Kitinoja *et al.*, 2011). The objective of postharvest technology is to maintain quality, ensure food safety, and decrease the food loss after harvest and before consumption (Kitinoja and Kader, 2002). Research and postharvest extension efforts focus on minimizing the loss and maintaining the quality of crops after production until consumption (Kader, 2003). Many techniques and technologies exist to minimize postharvest and quality loss at each stage in the postharvest system. Several postharvest suggestions are provided.

Crops grown where plants are in contact with soil or manure should be considered for a postharvest washing step. However, washing can cause qualitative loss due to abrasions from brushes and enhanced decay resulting from the water (Shewfelt and Prussia, 2009). When harvesting, care should be taken that fresh items do not come in contact with soil. The containers

used to hold harvest items should be free of debris and sanitized after each use. Plastic bins or buckets are easier to sanitize than wooden containers or woven baskets. Buckets are better containers for harvesting because they provide more protection than baskets. Baskets may squash the items resulting in bruising and mechanical damage (Kitinoja and Kader, 2002).

When fruits or vegetables are harvested at temperatures around ambient temperature, the high temperatures result in an extremely high respiration rate. The postharvest life of a product is inversely related to the respiration rate. Therefore, if possible, items should be harvested at cooler times during the day. It is essential to harvest at the ideal maturity so that producers are beginning with the high possible quality.

Maturity standards have been established for commodities to enable producers to harvest at the proper maturity. Each individual participating in harvesting should be trained to identify the proper maturity. In fresh fruits and vegetables size and external color are common indicators of maturity. Bananas posses an additional maturity indicator, the shape and angularity of the fingers is important when harvesting. Tomato maturity can be recognized by the gel formation and color inside the fruit. A shortened postharvest storage life can result from improper harvesting techniques: wrong tools, too early, or too late (LaGra, 1990). The most critical time in the postharvest handling system for most commodities is between harvest and the first time the fresh items are stored (Shewfelt and Prussia, 2009). Care should be taken when grading since untrained labor can damage the skin and allow for microbiological contamination (Saeed *et al.,* 2010). Fresh fruits and vegetables should be handled with care and attention. When an item is handled roughly, the handling can result in bruising and mechanical damaged to the flesh (Kitinoja and Kader, 2002). A simple reduction in rough handling can decrease the incident of mechanically damage in items like mangos (Kitinoja *et al.,* 2011).

The storage conditions of fresh fruits and vegetables play an important role in influencing the quality and postharvest loss. Cooling of fresh produce is essential. The act of cooling immediately after harvest is important to remove the field heat before the items are handled further. It is important that the cooling occurs as soon as possible after harvest. Delays in the pre-cooling will reduce the final quality and shorten the postharvest life (Kitinoja and Kader, 2002). In LDCs pre-cooling is not a common postharvest practice (LaGra 1990). Of the numerous handling techniques employed, temperature and relative humidity control are found to be most effective in fresh produce (Kader, 2002). Storage conditions can be improved when facilities utilize evaporative cooling. Structures can be made using natural materials like straw. If the straw comprising the walls and the room is wet in the morning, there is an evaporative cooling effect. Charcoal can be moistened and utilized to create a cooling effect (Kitinoja and Kader, 2002). It is also important to manage ethylene during storage and transport (Saeed *et al.,* 2010). Ethylene management can involve separation between ethylene producers and ethylene sensitive produce because the presence of ethylene can result in undesirable changes in product texture, flavor, or color (Kitinoja and Kader, 2002).

The packaging step of postharvest handling allows for a secondary layer of protection around the product during handling and allows for division of the product into manageable units (LaGra, 1990). In general, packaging material should be sturdy and vented. Packaging materials need to be sturdy to prevent collapse or items being crushed. The vents present in packaging material allow for the heat generated from the respiring fruits or vegetables to escape. The fresh fruit or vegetables should be packed into the containers gently. The items should not be packed too tight or too loose. Packing fruits or vegetables too tightly results in compression bruising

whereas items packed too loosely packed can bruise as a result of pieces vibrating against each other in the container (Kitinoja and Kader, 2002)

Methods customized to commodities can be used to ensure less damage to fruits or vegetables when they are transported. Bananas can be placed in containers in several arrangements to reduce the damage. Key steps would be to arrange the banana hands around each other layering small hands and then covering the smaller hands with larger hands to fill the container. When filling the container it is important to ensure that the crowns of the bananas do not touch the fingers. Simple structures can be constructed with limited resources. For example, a station for field packing can be constructed using sheeted plastic and wooden poles. The benefits of such construction are that is allows items to be packed in the field reducing the number of times it is handled. Additionally a thatch can be applied to the roof so that it will impart shade and cool the structure (Kitinoja and Kader, 2002).

Transportation methods should be analyzed to reduce damage to fresh fruits and vegetables. When loading vehicles care should be taken to reduce mechanical damage. A truck bed can be lined with straw or woven mats to prevent damage. The speed of transport should be determined by the grade and quality of the road as well as the quality of the trailer. Air pressure in tires can be lowered to reduce the impact of transport on fresh produce. Each time an item is handled the postharvest quality is impacted. Therefore, methods or harvesting practices that reduce the time fresh fruits or vegetables are handled is ideal (Kitinoja and Kader, 2002).

Additionally, when transporting fruits and vegetables over long distance proper management of the temperatures within the load of fruits or vegetables is important. Effective stacking of the load can allow for circulation and removal of respiration heat. Circulation also allows for removal of the heat resulting from the atmosphere or from the vehicle. When

transporting fresh items in sacks or bags utilizing a vent tube allows for reduction of the heat of respiration (Kitinoja and Kader, 2002).

Postharvest losses can also be the result of pathogen contamination. Fruits or vegetables can become contaminated during harvest. Following hygienic practices is important when harvesting items. Washing hands and blades used to harvest is necessary. Harvesting items should be restricted to those in good health (Kitinoja and Kader, 2002). Water in preharvest and postharvest activities could be a source of pathogen transmission to a fruit or vegetables. Additionally the contours and any small opening in the flesh can be an entry point for pathogen. Publications by the USDA support the prevention of microbiological contamination rather than methods of corrective action once contamination has occurred (Kader, 2003).

To address growing concerns of food safety in the produce industry, use of 'good agricultural practices' and 'good manufacturing practices' is encouraged at all steps of the supply chain (Kitinoja *et al.,* 2011). Effective postharvest treatments must be appropriate for both the product and the situation. The type of appropriate postharvest treatment differs based on the economy, infrastructure, quantity, and environment of a given market. Additionally postharvest treatments must account for specific markets and their needs considering the cost and feasibility of implementation of such treatments. (Shephard, 1993). Postharvest technologies can be small in scale since in developing countries most farmers operate in small scales with regard to the area of land cultivated and the amount of crops harvested (Kitinoja *et al.,* 2011).

Globally over half of the food supply is produced through the efforts of non-mechanized human labor. Therefore, low investment technologies that are simple might be the most appropriate solutions for producers with low volume, commercial operations with limited capital, and for producers involved in directly selling their product (Kitinoja and Kader, 2002).

Continued work in postharvest research is justified. Investments in postharvest research and new technologies yield a high rate of return compared to research on production methods. Focusing on postharvest research is beneficial to the overall public good; however, this also includes benefits to investors in the public sector. Additionally, continued research can have a distinct impact on poverty, health, and food security. Implementation of postharvest technology can also increase the sustainability of farming practices (Goletti and Wolff, 1999).

When researching new postharvest technologies and development plans for developing nations, there are several recognized challenges and needs. One challenge is the lack of knowledge of indigenous crops and the different handling recommendations for local varieties compared to the procedures for better known varieties (Kitinoja *et al.,* 2011). Developing countries have a unique set of socioeconomic factors that can hinder the implementation of potential postharvest technology solutions. Inadequate marketing systems, insufficient transportation infrastructure, government influence and regulations, lack of access to needed supplies, a lack of known information, and poor maintenance of facilities have been identified as socioeconomic factors influencing implementation of new technologies (Kader, 2005).

Available infrastructure presents a challenge, specifically, the available vehicles and roads. Vehicles available for transportation are not typically adequate for transport of fresh produce. Individual producers may not be able to afford a vehicle for transporting crops. One benefit from cooperatives has been the option to purchase proper vehicles; however, the lack of road infrastructure is still an issue. Even if proper postharvest practices are known, use of proper tools and equipment in developing countries is very uncommon. Accumulating the funds necessary to purchase can be difficult and the desired tools might not be available. Domestic markets do not always manufacture or import sufficient quantities of the tools. There is a need

for handlers to have the proper equipment to implement postharvest technologies. Some tools such as harvesting aids and packaging containers could be manufactured locally. A challenge to implementing technologies that involve facilities and equipment is when initial investments in facilities are made there must be a plan and additional funds allocated for repairs and maintenance. As with any development around postharvest loss, identifying the extent of loss is important. However, a quantitative loss in the number of fruits or vegetables is easier to calculate that than qualitative postharvest losses that occur. Quantitative losses allow for sorting and discarding of lost fruits or vegetables; whereas, there are little measurements of consumer quality loss and loss of overall nutritive content (Kader, 2005).

From LaGra (1990) to Kitinoja (2011) it is well established that any attempt to develop a successful strategy involving postharvest loss must first begin with a systematic analysis of the handling systems for each commodity. With concern to developing countries, Kader (2005) identified three strategies to reduce postharvest loss in developing countries. The first strategy is to assure the quality and safety of perishable products by applying the current body of knowledge to the postharvest handling system. The second strategy is to remove the socioeconomic hurdles that exist including undeveloped marketing systems and infrastructure. The third and final strategy is to encourage collaboration throughout the handling systems from producers to marketers. Solutions to problems in developing countries are found by applying existing technologies at the appropriate level rather than development of new technologies. However, in order to reduce postharvest losses overcoming socioeconomic constraints is fundamental. In LDCs making significant reductions in postharvest losses requires application of knowledge about postharvest handling to improve the handling system along with surmounting socioeconomic constraints (Kader, 2003).

Systems Background

Until the 1930's, the basis of scientific research was 'reductionism' where analysis of individual parts provided understanding to the whole (Andersen, 2001). This belief came before a shift in scientific thinking to a holistic method of analysis. Establishment of a system theory, based on holism rather than reductionism, is attributed to Ludwig von Bertalannffy. Systems theory was furthered by Ashby with the publication of An Introduction to Cyberkinetics in 1956. Modification of the systems approach considering the role of people as actors resulted in the creation of soft systems (Checkland, 1999).

Commodity system, *value chain*, and *supply chain* are terms used to describe the processes of production, harvesting, processing, wholesale exchange, retail exchanges, and collective supporting functions. Supporting functions include inputs, financial services, transportation, marketing, and packaging. Any of these terms can be used to describe the system (Kitinoja *et al.,* 2011). Supply chains of food systems differ from other supply chains because of long lead times along with characteristic uncertainty of supply and demand. These differences prevent implantation of supply chain controls that have been successful in other industries (Lowe and Preckel, 2004).

A systems approach is an organized method of viewing a continuum. The observer defines the system as multiple parts that are coordinated and interact to accomplish a specific purpose (Wilson and Morren, 1990). A system approach allows for seeking opportunities for improvements along a continuum (Shewfelt and Prussia, 2009). The application of a systems approach allows for addressing potential changes and their impact on the commodity system (Wilson, 1973).

Rigid formal systems are somewhat difficult to apply to food systems due to their complexity (Phillips and Unger, 1973). Food systems include all of the related activities from harvest through processing, preparation, or marketing. Losses either in quality or quantity can happen at any point during the food system (Hodges *et al.,* 2011). Agricultural food chains also include all and are influenced through the organizations responsible for farming, distribution, processing, and marketing (Ahumada and Villalobos, 2009). Applying systems to food chains is difficult because systems differ based on the commodity, the final use of the commodity and the accessible and affordable technology (Shewfelt and Prussia, 2009). Systems for perishable products are often missing a necessary function representing shelf life. Additionally, there are often modification of food supply chains in response to changing demands and distribution practices (Ahumada and Villalobos, 2009). However, it is agreed that when considering supply chains two or more processes should be analyzed in the same model for improved performance of the overall supply chain (Chadra and Fisher, 1994). While integrated models are more complex than considering one aspect, the potential benefits exceed the complexity (Ahumada and Villalobos, 2009). A complete model represents one commodity in a specific market (Phillips and Unger, 1973).

The systems approach has been applied with success to food supply systems, specifically postharvest handling systems. A systems approach addresses the connections between the operations occurring after harvest before delivery to consumers. Utilization of a system approach allows for predicting the impact of changes without actual modification of the system. A system approach can identify where there are gaps in knowledge and aid in prioritizing the efforts of researchers (Shewfelt and Prussia, 2009).

Systems thinking and models are theoretical frameworks that help to explain food supply chains. To advance supply chains to meet expectations of quality, safety, and value systems thinking is necessary (Prussia and Mosqueda, 2006) When applying a systems approach, the first step would be to define the boundaries of the system. The boundaries serve to display the interactions between the external environment and the system. The system can both affect and be affected by the external environment (Ikerd, 1993). The next step would be to identify the stages or steps within the system and the actors involved. A visual perspective of a system can be achieved through the creation of schematic (Shewfelt and Prussia, 2009).

The first application of a systems approach to postharvest handling was in 1981 through the combined efforts of four departments at The University of Georgia. Systems thinking was used to model food supply chains. This approach allowed for advancements within in the supply chain to meet expectations of quality, safety, and value. Within the softy systems approach, Soft Systems Methodologies (SSM) presented a way to address both the technical and social issues relevant to postharvest handling (Prussia and Mosqueda, 2006). Soft systems enable characterization of a system that acknowledges the variations to the system occurring from human activity (Zexian and Xuhui 2010). Use of systems approach in the handling of fresh fruits and vegetables gained acceptance in the industry when presented at a round table workshop highlighting how to improve the quality for consumers and reduce postharvest loss. The systems approach was applied to the creation of computerized models for peaches and blueberries demonstrating the impact of storage times and temperatures on final fruit quality (Prussia and Mosqueda, 2006).

In well planned and integrated supply chains, every step within the chain is managed with concern for performance of the entire chain and the potential impact of that step on the final

product quality (van Hoek 1998). A systems approach provides four advantages when considering food supply chains. Specific and broad problems within a system can be identified. The methods of applying systems approach provide objectivity needed to identify the proper solution for a specific problem. The methods also consider qualitative and quantitative descriptions of the system. Finally, the solutions produced using systems approach account for the entire transitional steps of the solution, not just the final outcome.

The traditional model for agriculture has been an industrial development model. The industrial development model land and plants are considered production units and the unit of a farm as a factory. The overall goal of an industrial model is that through increasing production the overall well being of human's increases as a result of employment and income. Strategies used in industrial development are to increase economic efficiency through specifications, use of routines, and mechanization of large scale production (Ikerd, 1993). Within the industrial development model, the quality management principles used in companies could have application in fresh produce handling (Prussia and Mosqueda, 2006). The movement from the component analysis of industrialized farming to systems analysis of farming and communities is necessary to address concerns regarding both the environment and social challenges (Ikerd, 1993).

This movement is necessary to address environmental and social equity movements within the United States. The trend of using systems approach has been to address agricultural systems that can also practice sustainability, improve farmer's quality of life, and still be commercially viable. This new agricultural model focuses on managing resources within the farms to influence the ecological impact of the farm (Ikerd, 1993).

Systems in developed countries are based off financial gain and competitive advantage with supermarkets as the main driver (Hodges *et al.*, 2011). The traditional landscape in the US and UK is dominated by large corporations and retailers that push for mass production of food through a very globalized and mobile supply network (Ilbery *et al.,* 2004). The category of fresh fruit and vegetables is a profit driver for retailers. However, the fresh fruit-and- vegetable category is hard to manage since fruits and vegetables are seasonable, affected by weather, perishable, and sourced through many producers with varying practices (Collins, 2003b). The fast food industry has been more successful in managing produce supply chains than retailers (Kaufman *et al.,* 2000). One global fast food chain's lettuce supply chain functions with low margins, product specification, and efficient processing and handling compared to retail practices (Collins, 2003b).

The agriculture sector in the US is moving towards vertical co-ordinations. Co-ordination ranges from complete vertical integration to selling at an open market. In vertical integration, all of the steps of the supply chain are coordinated from the producer to the retailer. Changes towards vertical integration are the result of firms attempting to differentiate their brand and maintain quality. The advantage of vertical integration is that reduced monitoring costs make guaranteeing quality easier. These changes are demonstrated by the increase of contracting that is shown in the US agriculture system (Hobbs and Young, 2000). New analysis of systems is being conducted using supply chain management. Supply chain management is a type of conceptual framework for describing the systems of food and all steps until consumption. Supply chain management is based off of business models to picture logistics, economic, marketing, technical, and human aspect of the system (Collins, 2003a).

In the United States, there is a push to decrease the number of developments and in turn preserve farmland and create a community based food system. The push is a result of trying to break the dependency on the current global food system. The result of such concerns in the US is the community food system approach and the farm to school program. The community food system approach considers sustainability, health, environment, social, and economic justice. These systems lower the barriers that typically exist in industrial agriculture between the consumer and the farmers. Farm to school programs focus on agriculture in a regional framework (Vallianatos *et al.,* 2004). Some changes in the analysis of agricultural supply chains are a result of public health issues. Supply chains must be able to undergo more regulations and closer monitoring (Ahumada and Villalobos, 2009). In urban environments, there is a need for understanding and visibility of food systems in urban planning (Koc and Dahlberg, 1999). Sustainable agriculture is based on a holistic or systems model. In sustainable agricultural, people are classified as part of the system from which they draw well-being and quality of life. The consideration of whole systems allows for the recognition of qualities and characteristics not specifically a part of any one component in the system (Ikerd, 1993).

Differences in the supply chains in the US and UK are a result of efficiency in the UK's system. The transport and inventory system for fresh salads in Europe is half of that in the US enabling better quality and reduce waste (Fearne and Hughes, 2000).

Europe was studying food supply chains well before the United States. France and Great Britain both have a history of receiving frozen shipments of meat from colonies beginning in the 1880s (Rodrigue and Notteboom, 2013). However, the traditional commodity trading system is being challenged in the UK through retailers that are pushing the importance of private label in the produce market (Fearne and Hughes, 2000). In England there is a high presence of

supermarkets in the distribution of food to the consumer. The supply-chain-management practices of supermarkets altered the traditional food distribution network. Analysis of these modified food distribution systems has been through business models (Cadilhon *et al.,* 2003).

The last decade has shown an increased in concern around current food systems. This concern and scrutiny reflect the public concerns of food safety, health, and environmental concerns with industrialized practices. An analysis of supply chains found that several socio-economic values can be gained through localizing, shortening, and improving the synergy of supply chains. The analysis considered the shift from economics of scale to economics of scope and the impact of synergy of the entire operation (Ilbery *et al.,* 2004).

In 1990 Food Safety Act modified the vertical co-ordination found in the food supply system. Instead of the process being driven by the growers the Food Safety Act allowed the retailer to be the driver since they must take steps to ensure safety of products purchased from suppliers. Risk management served as the driver for more coordination in the supply chain for fresh fruits and vegetables. In modification of the supply chain, actions were taken to reduce costs, and give the retailer more control via partnerships or growers networks (Fearne and Hughes, 2000). The governmental Policy Commission for Future of Farming and Food established a Food Chain Centre due to rapid changes in the red meat industry resulting from increased demand to supermarkets. The governmental Policy Commission for Future of Farming and Food established a Food Chain Centre (Simons and Taylor, 2007).

The Food Chain Centre in the UK has applied the Food Value Chain Analysis, FVCA, to dairy, horticulture, and cereal, and red meat chains. The application of FVAC to value added red meat products has shown potential logistical benefits within the chain, identification of

implementation issues, and potential of organizational stability of the chain over time (Simons and Taylor, 2007)

An argument supports the new systems approach is that the commodity systems analysis along with research on distribution and retail outlets does not fully describe the industrialized food system. Jane Dixon proposes a "cultural economy" model accounts for understanding to gender, consumption, site of production, paid and unpaid work, and exchanges that occur outside of a traditional market (Koc and Dahlberg, 1999).

With the postharvest handling systems, all stages are connected and actions or decisions made at one point stage can affect postharvest losses at other stages (LaGra 1990). Understanding a commodity system as a whole from production through distribution allows for the planning of effective development. Phillips and Unger (1973) speculated that development agencies could accomplish more in the area of agriculture and in the development of agricultural business if a broader and increasingly systematic approach was used. Applying a systems approach to postharvest handling provides two distinct benefits: (1) characterization of all factors affecting quality, safety, economic and social aspects and (2) identification of key actors and actions within the system. Areas that the need improvements are identified and the impact of new postharvest technologies become evident by mapping the system (Zexian and Xuhui, 2010).

Extended shelf life is a result of widespread cold-chain systems in developed countries. The food distribution system in developed countries is continually improved through management practices and new technologies that increased efficiency (Hodges *et al.*, 2011). The highly specialized cold-chain system presents an opportunity for developing countries to enter into the global market spurring economic development (Rodrigue and Notteboom, 2013). Least Developed Countries (LDCs) refers to countries that have low GDP on a scale of comparison to

members of the Organization of Economic Cooperation and Development. Additionally LDCs are countries where the majority of results come from small stakeholders (Hodges *et al.*, 2011).

One application of a systems approach in developing countries has been the use of Commodity Systems Assessment Methodology (CSAM). CSAM methodology allows for analysis of entire commodity systems. During analysis problems throughout the system can be identified and prioritized based on how they fit within the system. Analysis of the whole system and prioritization of problems results in development of the most effective and realistic solutions. CSAM methodology utilizes many different instruments, techniques, and analysis techniques through one integrated document. The methodology was developed as a result of many years of research and has been tested in multiple countries by dozens of professional. Using CSAM to analyze a commodity system requires identifying points of inefficiency, actions that are increasing the cost of the product, and market specific solutions. The benefit of utilizing CSAM can be seen in the results produced that include an account of the commodity system with principal components, participants, and roles identified, problems identified by priority within each component and the cause of each problem, potential solutions for each problem with priority given for the best solution, and sufficient data to consider projects and complete profiles (LaGra, 1990).

> "In Africa recent starvation, mass-scale hunger and hunger-related deaths have not been triggered by an absence of appropriate crops. The truth is more complicated. Hunger is the result of a cluster of factors, including armed conflict, resource shortages, blood diamonds, recovery from the Cold War, and the dismantling of existing social mechanisms (so called 'moral economies') designed

> to mitigate food emergencies, whether caused by the climate or by human factors." (Patel, 2007, p. 148)

Considering life in rural Africa it is noteworthy to consider the society, the type of agriculture, and the environment. In traditional roles the women in Sub-Saharan Africa provide most of the daily labor for farming. Rural life is often characterized by subsistence farming that impacts the food supply, personal income, and employment. The subsistence farming practiced is characterized as low resource agriculture. This combination of factors increases the need for technologies that are low risk and low cost. Additionally, taking into account the specific climatic conditions, soil composition, and presence of pests and diseases present in the area is vital (Navarro, 2012). Increased crop yields sometimes have alterative effects other than increased sales at a market. In the case of subsistence farming increased yields or decreased loss can result in increased consumption providing nutritional benefit rather than economic benefit that can be assessed with a cost benefit analysis (Shephard, 1993).

Human-activity systems involve the actions and decisions of people. It is necessary to consider the motivation and incentives of individuals to adopt potential new technologies. With consideration of new postharvest technologies, it is necessary that farmers see a direct correlation between new handling techniques and monetary returns at the market (Shephard, 1993). Many outside, pre-existing conditions contribute to the postharvest handling system. Recognizing the influencing factors and the overall social, political, and economic situation of an area are necessary to account for the human interactions in the postharvest handling system. Even more it is important to consider the influencing factors and overall situation of an area when suggesting new postharvest technologies. Including the steps of distribution within in the system requires

the acknowledgement of wholesalers, formal, informal, and modern retailing. This system includes markets, supermarkets, and even street food (Aragrande and Argenti, 1999).

When considering the role that rural areas in developing countries have in supplying urban areas with food, additional handling steps occur. Commodities must be packaged, stored, processed, and finally transported. Some of the markets present in developing countries have not expanded with the increased quantities of food demanded by urban markets. Specifically, storage space and traffic congestion are issues within current markets. As countries recognize the need for specialized wholesale markets, there is also a need for supporting infrastructure and additional facilities as countries adjust to a liberalized economy (Aragrande and Argenti, 1999).

Priorities in developing countries have switched from a technical approach of reducing postharvest loss to now a holistic approach. The holistic approach considers the activities of production, processing, distribution, marketing, along with the interactions between the activities (Mrema and Rolle, 2002). Markets that are successful require a consistent supply of good fruits and vegetables. Implementing technologies to reduce postharvest quality loss could increase the supply of quality fruits and vegetables (Hodges *et al.,* 2011).

Aid for Trade (AfT)

The systems of postharvest handling in LDCs need sizable investments to develop a formal market system that improve performance to impact postharvest losses. Needed investments include public infrastructure like road conditioned for all types of weather. Also, market institutions should be developed to where groups or individuals can correctly respond to demands in the market (Hodges *et al.*, 2011). In developing counties there are many problems surrounding roads and transportation specifically if roads exist if those roads connect farms and markets, and if their vehicles are in proper repair (Kitinoja *et al.*, 2011).

Development revolving around the economy typically requires procedural changes along with changes in the available facilities and institutions, (Phillips and Unger, 1973). The current value chain must be understood in order to develop sustainable interventions to a system. In addition, more than one intervention might be necessary for an effective change to be made. Interventions should be managed through external agencies with support for either public or private sector agencies (Hodges *et al.*, 2011).

International or foreign aid is the charitable and completely voluntary transfer of one country's resource to another country with the goal of improving current situations or long term development within the country. However, it is worthwhile to note that when aid is given it is not always purely altruistic. There are many forms in which aid is given, and many groups can give aid. International aid typically falls within two categories, either humanitarian aid or development aid. Humanitarian aid is emergency aid to address pressing situations in foreign countries. Developmental aid focuses on the development of the receiving country's social, political, economic, or environmental situation.

Modern implementation of aid began in the end of the 19th century and beginning of the 20th century. This aid began with the western powers and their rule over colonies, along with the recognition of poorer countries (Kanbur, 2003). Two decades ago, the 1990's were a time of 'aid fatigue' because of the concern over the dependency that poorer countries might be developing from the continual foreign aid (Thorbecke, 2000). Also, there has been some debate that some types of aid, specifically food aid, can harm a developing country because it supports the cycle of inefficient agricultural and economic policies (Schultz, 1960). Opposed to the continuous cycle of providing aid each year for countries and increasing their dependence on the trade, AfT

provides support for countries through providing necessary infrastructure for global trade. Increased global trade promotes economic independence for individual countries.

AfT is defined by Deadroffs' Glossary of International Economics as, "the strategy of promoting economic development by helping countries to create or improve the infrastructure needed to facilitate international trade." The concept and use of AfT has grown within recent years with support from both the donor countries and recipient countries. However, even with increased use there is little analysis of the impact and effectiveness of this type of trade.

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CHAPTER 2

ANALYSIS OF POSTHARVEST SYSTEMS OF FRESH PRODUCE IN RWANDA

Introduction

The period of time and storage conditions of fruits and vegetables between harvest and consumption impact the quality. The conditions and handling of fresh produce are important as the items are living tissue and continue to be physiologically active after harvest. The respiration rate of fruits and vegetables along with any processes applied to them impact the final quality. A decrease in the quality of fresh produce items is harmful as it leads to consumer unacceptability or waste. Quality loss expected after harvest is referred to as postharvest loss.

Key examples of postharvest loss include bruising, excessive softening due to improper maturity at harvest, water loss, decay, and chilling injury. The majority of postharvest losses are the result of improper handling, damaging fruit tissue, insufficient cooling, along with failing to maintain ideal storage temperature. Also, failure to sort and remove low quality items along with inappropriate packaging materials and methods contribute to postharvest loss (Kitijonia *et al.*, 2002). The modification of storage conditions and handling practices to extend shelf life and increase the quality of fresh items is referred to as postharvest technology (Shewfelt and Prussia, 2009).

Postharvest treatments refer to actions or processes that are performed on fresh items including but not limited to storage, washing, grading, sorting, or transportation. As described by Kader (2002), the goal of any postharvest method is to maintain quality and safety of the harvested fruit or vegetable. The established methods for controlling postharvest loss are use of

appropriate genotypes, integration of management techniques for crops, and use of proper handling techniques. Of the numerous handling techniques employed, controlling temperature and relative humidity control is found to be most effective in fruits and vegetables. Effective postharvest treatments must be appropriate for both the agricultural product and the situation. Postharvest treatments differ depending on the economy, infrastructure, size of harvest, and characteristics of the market. The size of the market should be considered to determine the cost benefit analysis and feasibility of implementation (Shephard, 1993).

A Systems Approach

There is a recognized need to reduce postharvest losses in both developing and developed nations. However, it is difficult to determine the points within the postharvest handling system where the needs are the greatest and where new technologies could be implemented. Even when solutions are developed, the technology can vary if the given commodity is grown in an alternate location or under different circumstances. Postharvest technologies can be developed by focusing on crop physiology, and establishing the best methods for indigenous crops and local varieties (Kitijona *et al.*, 2011*)*. Postharvest technologies should be implemented in locations where they will be effective and profitable. Management interventions must account for a specific market's needs, the cost to the market, and the feasibility of implementation. In some cases, application of small-scale technologies can be the best solution for the producers of a given market. Postharvest technologies must account for a specific market's needs, the cost to the market and the feasibility of implementation. There are certain cases where economic efficiency may not be as important as to gain social benefits such as food security (Shephard, 1993)

While it is important to identify the specific challenges and needs of a postharvest handling system, the entire system should be considered, not just specific unit operations.

Applying a systems approach to postharvest handling provides two distinct benefits: (1) characterization of all factors affecting quality, safety, economic and social aspects and (2) identification of key actors and actions within the system. Through system mapping, areas for improvement are identified, and the impact of new postharvest technologies becomes evident (Zexian and Xuhui, 2010).

Utilizing a soft systems approach allows for characterization of a system acknowledging the variations that occur due to human activity (Zexian and Xuhui, 2010). One of the core concepts of a soft system is the idea that industries and individual businesses can be characterized as systems (Checkland, 1999). The agricultural sector in developing countries can be considered an industry. Optner (1965) suggests the following rationale for using a systems approach for understanding of the postharvest handling systems within the agricultural sector:

- A systems outlook allows for determination of general and specific properties that relate to a problem.
- The methodology of system approaches focuses on the solution process including transitional steps and variations opposed to solutions that focus merely on the final outcome.
- The nature of systems methodology provides an objective standard which can then be used to organize the solution to fit the process correctly.
- A systems methodology accounts for both qualitative and quantitative descriptors recognizing the interactions between qualitative factors and quantitative factors providing better quantitative solutions than just analysis of quantitative factors.

The analysis of human activity systems is distinctly different from a hard system analysis. The analysis must recognize the observer who is characterizing the system and the viewpoint of the

observer at that time. Additionally, the testing of a human activity system is different because there is no established method for testing the system. Instead, the model can only have specific accounts that can be proven valid with consideration to the system (Checkland, 1999).

The benefit of using a systems approach to understand the postharvest handling system is that it provides a framework for characterizing the current handling system and accessing the impact of new technologies (Checkland, 1999). Figure 1 displays the activities of a systems approach. The activities correspond to the understanding of the postharvest handling system in the following ways:

- Finding out the situation: Documenting the postharvest handling system from the farmer to final consumer
- Exploring by models of purposeful activity system based on worldviews: Analyzing the activity system with regard to quality, food safety, economic, and overall concerns.
- Discussing and debating the situation based on the model: Drawing information from academic sources and discussing potential technologies and their impact.
- Taking action to improve the situation: Working with system actors to develop alternative strategies to achieve specific goals.
- Critical reflection on the inquiring process: Analyzing the intended and unintended effects when introducing these alternative strategies and testing solutions iteratively to improve performance of the overall handling system.

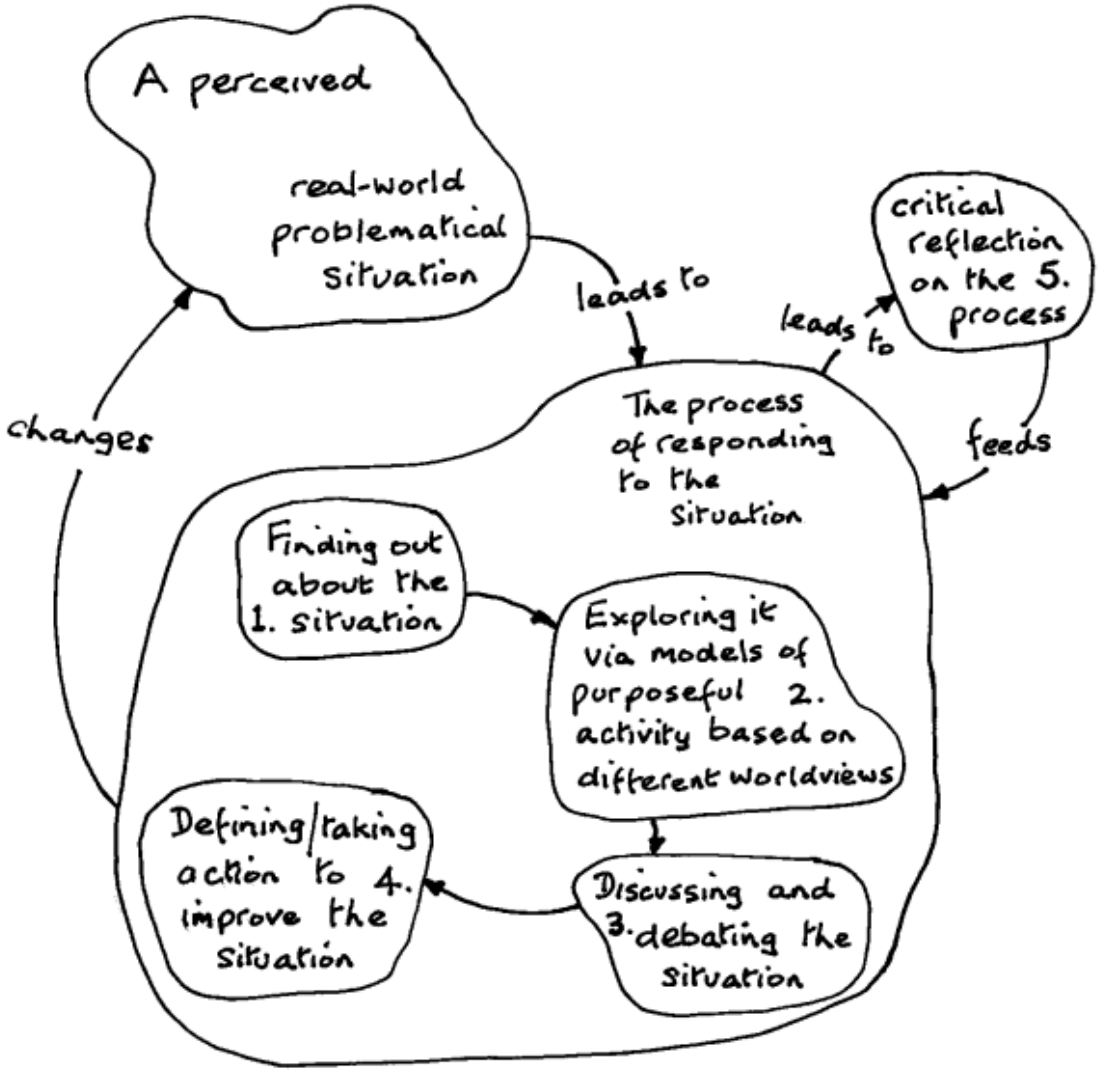

Figure 1. Schematic of the Application of a Systems Approach to a Generalized System

(Checkland and Poulter, 2006) Reprinted with permission of John Wiley and Sons Ltd.

The Commodity Systems Assessment Methodology (CSAM) is one tool used to diagram food systems. The CSAM was developed by the Postharvest Institute for Perishables and is used to identify problems and create solutions. CSAM considers all participants and their roles in the commodity system. Figure 2, Participants in the Commodity System, shows stages within the commodity system and provides examples of those partictipating in each stage.

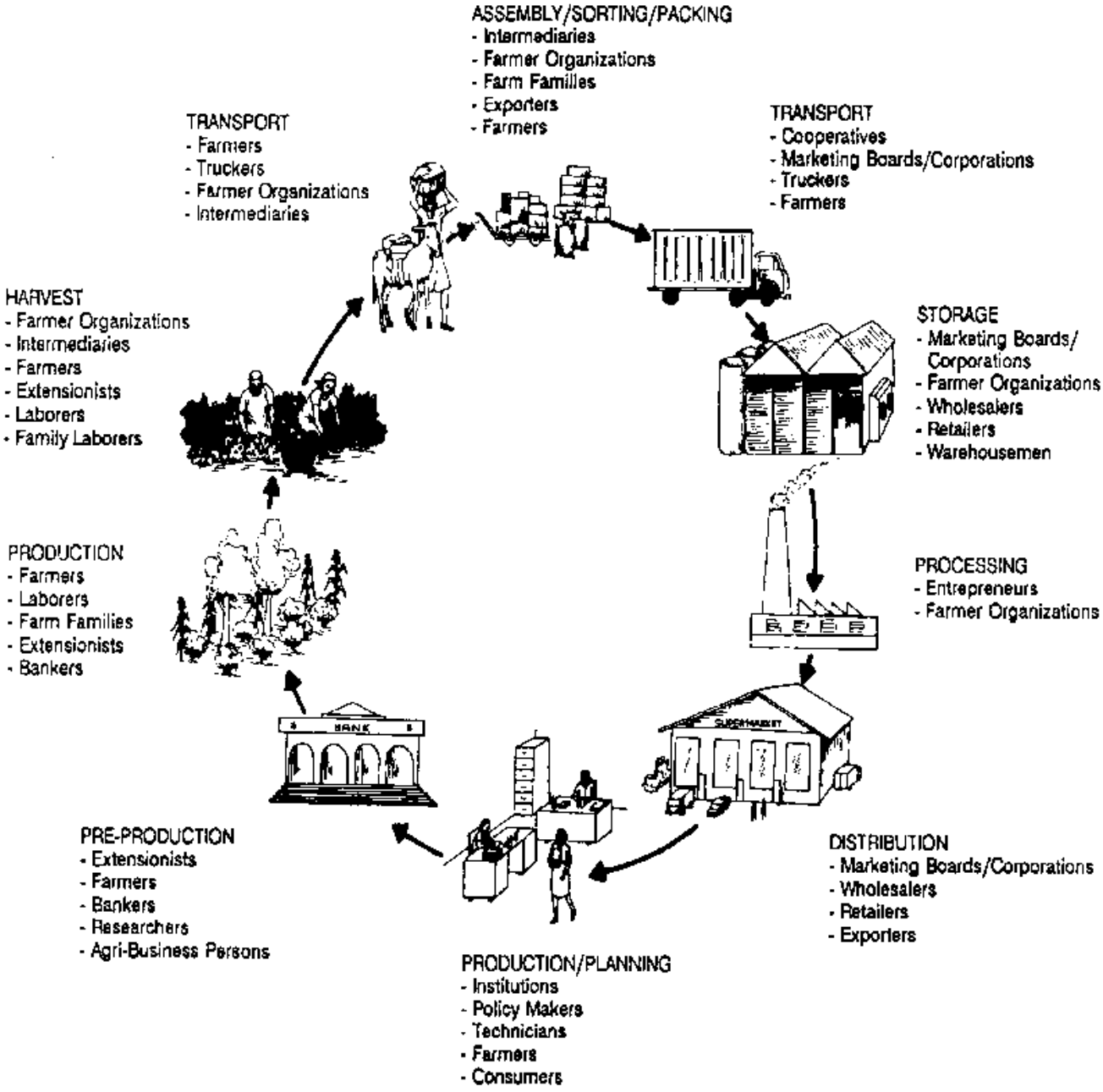

Figure 2. Participants in the Commodity System

(LaGra, 1990) Reprinted with the permission of University of Idaho College of Agricultural and Life Sciences.

The CSAM utilizies the expertise of individuals already present small teams are able to investigate and within the country. One of the benefits of CSAM is that describe a commodity system. Completion of a commodity systems analysis can provide an understanding of the observed postharvest losses. The unit operations during which quality loss occurs and the responsible party can be determined. The specific marketing or handling practice responsible for the postharvest loss can be identified. Analysis using CSAM provides the framework for characterization of the economic relationship between quality loss and the cost expense of implementing a new postharvest practices (LaGra, 1990).

Commodity Systems Analysis Methodology (CSAM) focuses on four components: pre-production, production, postharvest, and marketing. The pre-production component includes the importance of the crop, governmental policies, relevant institutions, facilitating services, producer and shipper organizations, environmental conditions, and availability of planting material. The production component addresses farmers' general cultural practices, pests and diseases, preharvest treatments, and production costs. The third component, postharvest, considers harvest, grading and inspection, postharvest treatments, packaging, cooling, storage, transport, delays and waiting, other handling practices, and agro-processing. The fourth component, marketing, regards market intermediaries, market information, consumer demand and preferences, and exports (LaGra, 1990). The Data Collection Worksheet includes both qualitative and quantitative measurements. The Data Collection Worksheet addresses many of the same topics as the CSAM. The topics addressed include quantitative data regarding sorting, grading, decay, damage, storage temperature, humidity, pulp temperature, and °Brix. Additional information was collected in reference to planting materials, farming practices, pests, pre-harvest

treatments, production costs, harvests, grading, postharvest treatments, packaging, cooling, storage, transport, delays, and other handling.

Grounded Theory

In a grounded theory approach, qualitative data can be analyzed to determine theories or conclusions. A grounded theory approach considers the context of the data analysis along with the individual perspective and knowledge of the data reviewer (Charmaz, 2006). Widely accepted definitions of grounded theory, or process to follow for its application, do not exist. Instead, several influential individuals have shaped the history, application, and processes of grounded theory within the social science research. Corbin and Strauss (2008) and Charmaz (2006) have presented unique perspectives and approaches to grounded theory.

A grounded theory approach considers all aspects of research involving social processes including data collection, data analysis, and developmental of theoretical frameworks of the studied system. During early data analysis, grounded theory requires the researcher to be aware of emerging themes and seek out social processes described by the data. Inductive reasoning is used to create frameworks to describe the process including causes, conditions, and consequences (Charmaz, 2006).

Data analysis involves coding of all collected data. Open coding requires that data be considered analytically to allow for recognition of new theories and phenomena existing within the data. Open coding compares all interactions, and activities are compared both for similarities and differences. Also, similar events and activities are grouped together to form categories. The continuous questioning and comparison of data in open coding minimizes the subjectivity and bias of the researchers (Corbin and Strauss, 2008).

After the development of conceptual frameworks, the frameworks must be compared back to the original data to ensure that the frameworks represent and fit the collected data. Additionally, the framework must be a useful model that represents the system, must be relevant in that model, and must provide an explanation of the process. Finally, the basic theory and skeleton of the frameworks must be transferable for application in another system at another place and time.

The grounded theory approach as proposed by Charmaz (2006) does not provide a specific prescription of methodology or steps within a study. Instead, Charmaz presents grounded theory as a set of flexible guidelines allowing outside elements (literature, other research, experience) to be considered and used. This specific approach to grounded theory also allows for modifications and changes to be made to the research during the entire process. However, the systematic process of grounded theory must be followed including two steps of data analysis. The initial analysis of data involves an open minded evaluation of data looking for data-driven concepts. The final stage of data collection involves integration of data driven results with outside knowledge and interpretation. The interpretations of the researcher are influenced through the researcher's past pursuits and interactions; Charmaz supports this interpretation as a part of a grounded theory approach. The final stage of the data analysis is used to develop proposed theories and theoretical frameworks.

Methodology

In an effort to represent the postharvest handling system several models of the system were created. The models were created using data gathered in Rwanda using Data Collection Worksheets and CSAM Questionnaire. The data were gathered by the World Food Logistics Organization and the University of California Davis for the Appropriate Postharvest

Technologies project funded by the Bill and Melinda Gates Foundation in 2009. The data involved four crops: pineapples, bananas, tomatoes, and amaranth. CSAM Questionnaires and Data Collection Worksheets were completed by farmers, wholesalers, those involved in retail sales, extension agents, and processors. The CSAM focuses on four components of the commodity system the pre-production, production, postharvest, and marketing components. Individual areas of focus within the components provided specific questions for the CSAM questionnaires. Regarding pineapples, fifty-eight CSAM Questionnaires and Data Collection Worksheets were collected; the distribution of the respondents is displayed in Table 1.

Table 1. Distribution of Responses for Pineapple Data Collection

Data Providers Form	Farmers	Wholesalers	Retailer	Extension Agents/Processor	Total
CSAM	10	0	2	14	26
Data Collection Form	11	11	10	0	32

CSAM Questionnaires were only collected from banana farmers and wholesalers, as shown in Table 2.

Table 2 Distribution of Responses for Banana Data Collection

Data Providers Form	Farmers	Wholesalers	Retailer	Extension Agents/Processor	Total
CSAM	2	9	0	0	11
Data Collection Form	9	6	25	0	39

The data collected from tomato farmers, wholesalers, and retailers included both CSAM Questionnaires and Data Collection Worksheets. Table 3 shows the number of responses collected from the participants in the commodity system.

Table 3. Distribution of Responses for Tomato Data Collection

Data Providers Form	Farmers	Wholesalers	Retailer	Extension Agents/Processor	Total
CSAM	4	4	4	7	19
Data Collection Form	9	8	10	0	27

The least amount of data were collected regarding amaranth production and marketing. Wholesalers were the only source of responses, as Table 4 reflects.

Table 4. Distribution of Responses for Amaranth Data Collection

Data Providers Form	Farmers	Wholesalers	Retailer	Extension Agents/Processor	Total
CSAM	0	4	0	0	4
Data Collection Form	0	0	0	0	0

Overall 158 individual CSAM Questionnaires and Data Collection Worksheets were completed. These were completed through interviews. The data were recorded on hand written sheets with the responses of interviewees in English. The data on each sheet were entered into an excel document for each commodity. Data included over 6,000 individual cell entries. The responses were coded with the commodity name, interviewee number, and alphanumeric code for the question being answered.

To complete the systems approach, scientific literature, past knowledge and experience, and the collected data were analyzed following the conceptual framework of grounded theory as proposed by Charmaz (2006). The open-ended data were analyzed to determine what themes emerged from the data. The themes were used to shape the representation of the postharvest handling system. The systems approach identified the steps within the postharvest handling system. Next, the major actors and input into the system were determined. Preliminary models of

the postharvest handling system were drawn by hand. These preliminary models were modified for better clarity and for a truer representation of the system. There had been three versions of the models before the final teardrop shape was established.

All research must possess a level of trustworthiness. In qualitative research, trustworthiness can be established through factors of credibility, transferability, dependability, and confirmability (Lincoln and Guba, 1985). In this study, credibility has been established through efforts of peer debriefing and member checks. Thick descriptions serve to establish transferability. Dependability has been proven through inquiry audits and confirmability has been established through an audit trail.

The generalized model, as represented by Figure 3, was then modified to relate solely to the pineapple postharvest handling system highlighting key areas or factors that were unique to pineapples, shown in Figure 4. The model was analyzed in Figure 5 with regard to how economic factors influence the system. Figure 6 represents a model of the postharvest handling system with regard to how food safety issues could arise, and specific instances where modifications could reduce food safety risk. In summary, all the previous models were considered, and Figure 7 represents the overarching concerns present in the postharvest handling system. In an attempt to give recognition to the socio-economic factors, one final model, shown in Figure 8, was produced. In the final model, the conditions outside of the handling systems were documented and the areas of influence were identified.

Results and Analysis

In order to facilitate reading and comprehension of the models, the following system was used to indicate which piece of data is being used (first letter of the commodity being referenced, interviewee number, interview prompt from the data recording).

From the analysis of the coded data themes emerged representing the postharvest handling system in Rwanda. Figure 3 represents the generalized model that was created. Within the closed teardrop shape are all activities of the postharvest handling system. The blocked areas within the teardrop are the unit operations in the postharvest system and the individuals who perform actions or tasks at each step. Under each unit operation are actions or treatments that influence the final fruit or vegetable quality. The items outside the teardrop are inputs into the system including containers, labor, rent, manure, seeds, supplies, fertilizer, and irrigation. There are five major activities in the postharvest handling system. The first step in the system is Farmers/Labor. This is the only step in the system that occurs in the field environment; during this step the fruit or vegetable is harvested. From the step of Farmers/Labor, the flow of goods continues either to Market or Wholesaler/Labor. Some of the goods directed towards Wholesaler/Labor are then routed to the market, as well. An alternate path from Wholesaler/Labor is to Retailer followed by processing at Agro-processing.

Starting from left to the right on the model the inputs into the system are shown outside of the teardrop. Then, within the teardrop on the left side the activities that occur within the field. Farmers/Labor occurs within the field and is influenced by the pre-existing conditions of the environment. The dividing line in the middle of the teardrop is dividing pre-harvest and postharvest activities. The arrows represent transportation: distance and mode. The operations that occur on the right side of the teardrop including Market, Wholesaler/Labor, and Retailer are postharvest activities. These postharvest activities are influenced by pre-existing conditions of temperature and relative humidity at the location of each activity. Also, during the postharvest stage there are inputs into the system from outside of the teardrop consisting of containers and labor. The final operation Agro-processing occurs outside of the teardrop on the right side. A

model of the postharvest handling system in sub-Saharan Africa was created in order to characterize and better understand the effect that different unit operations and actions have on postharvest quality. The responses of interviewees were used to create a model representing current postharvest practices.

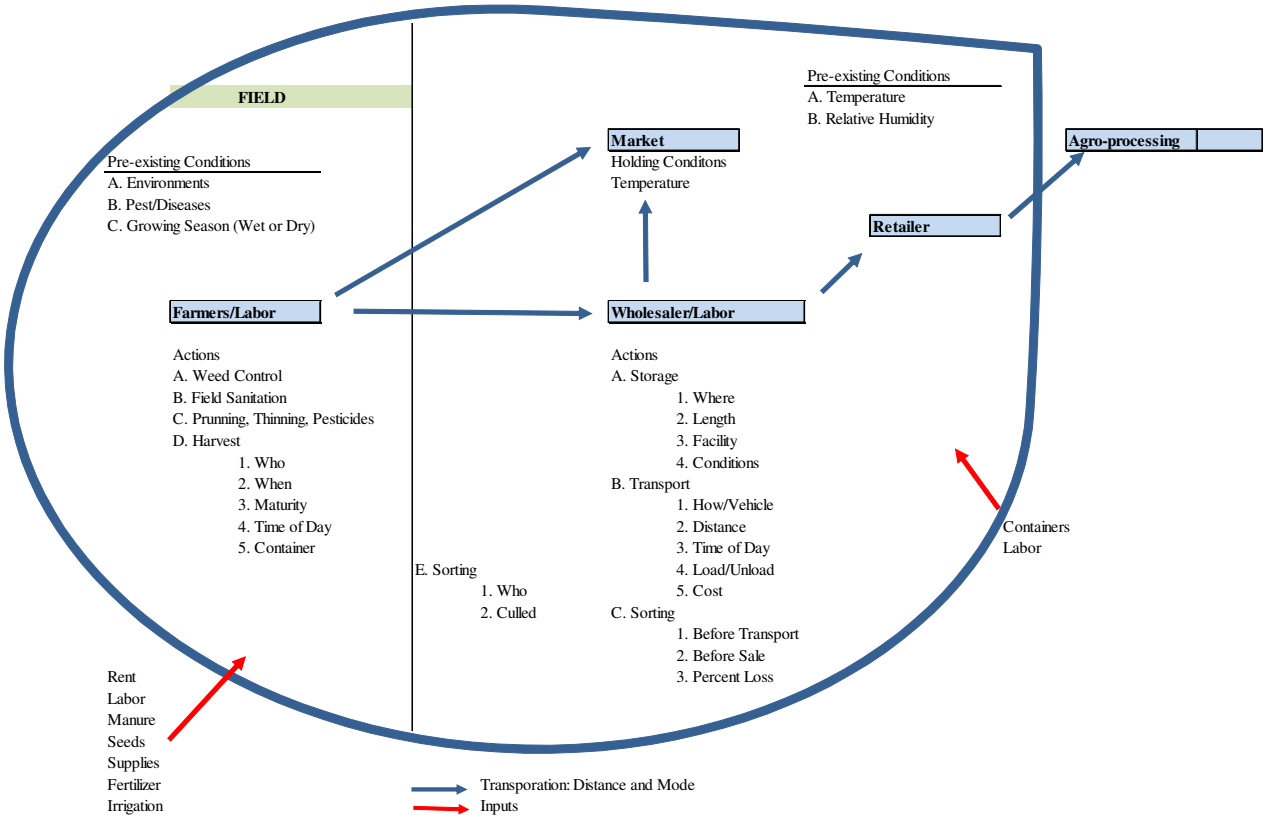

Figure 3. Generalized Postharvest Handling Systems. Figure 3 provides the model for the postharvest handling system. This generalized model was created from the data collected by the WFLO report for BMGF Appropriate Postharvest Technologies project, (Kitinoja 2010) from Rwanda in 2009.

Figure 3 displays individuals, factors, and conditions that influence the quality of fruits and vegetables. Beginning at the left side of the model the inputs into the system which impact the quality of fresh fruits and vegetables are shown. The quality of inputs available and purchasing methods is important to the postharvest handling system. The quality the starting material used impacts the final quality of fruit produced. Four farmers (P,51,X) (P,52,X)

(P,53,X) (P,54,X) expressed the belief that adequate planting material was coming from Uganda. These responses are important because of a contradictory response from an extension agenda (P,63,X) “The material from Uganda isn’t but PARCIU has distributed good planting material (these inspected and certified).” Not only is there an issue of availability of planting material there is a misunderstanding regarding the quality of planting material. While banana farmers were unaware of quality issues, a tomato farmer was aware of quality issues with seeds. One interviewee, (T,6,X) responded “Seeds are not adequate quality, Bought of bucket of tomatoes from which seeds came from, susceptible to disease.” Poor quality starting materials will negatively impact the final quality of fruits or vegetables. The response identified the importance of purchasing methods. Whether or not adequate supplies exist and whether or not farmers purchase them is affected by the availability of funding (P,51,Y) explains “They are available but they can only buy them when they have money.” The quality of inputs into the postharvest handling system depends on the availability of goods and ability of individuals to purchase materials.

Within the closed postharvest system, two activities at the Farmers/Labor step were identified as important. Harvesting methods and whether or not sorting was carried out were determined to influence postharvest quality. Farmers carried out a variety of harvesting methods. One specific practice was described (P,54,AS) as “Harvested at least twice a month using knives or panga by a farmer or buyer in the early morning or evening to protect from high sunshine, to protect hands from injury and the buyers presence.” The response validates the importance of harvesting produce at specific times, both to maintain quality and satisfaction of purchasers. However, not all farmers had the same reasoning behind harvesting methods. One farmer (T,7,AW) explained that harvest occurred “Two days before market, depends on available free

time." The variation between harvesting methods shows how improper harvesting methods could be a source of postharvest loss within the postharvest handling system. Similar to harvesting practices whether or not sorting occurred varied for individual producers. An interviewee provided an example of their practices, (T,5,BA) "Removes malformed and diseased, removed smaller sized ones". The previous sorting practices included removing diseased or malformed items, which is important to maintaining quality of the remaining items. This critical step was not always practiced. One producer, (B,9,BA), only sorted with regard to, "According to size and weights." Those producers that are failing to sort out low quality or damaged fruit could be increasing postharvest losses during storage and transport.

Under the Wholesaler/Labor operation storage and transport were identified as two important activities. A variety of storage methods were reported with very little modification of storage conditions for extended postharvest life. Storage conditions of pineapples during delays was described by (B,53,BJ) as " in a wooden box under the table in the market," and initial storage conditions of pineapple by (P,60,BS) as "In a room without other facilities no package, room 27 C for max 3 days." A lack of specialized storage facilities or storage practices can result in increase postharvest loss; therefore, storage was determined to be an influential step in the postharvest handling system.

The transportation step of the postharvest system was also identified to have an impact on fruit and vegetable quality. Many modes of transportation were used from trucks, cars, to bicycles. Also, the distance of transport varied widely. One respondent (B,60,BU) described transport to be "had 120 km in a truck," whereas (T,10,BM) described their transport as "On head, walking 1 hour and 30 minutes." Transportation affects the quality of fresh fruits and

vegetables. Knowing the specific mode and distance of transport allows for better predictions of what impact transport will have on postharvest quality.

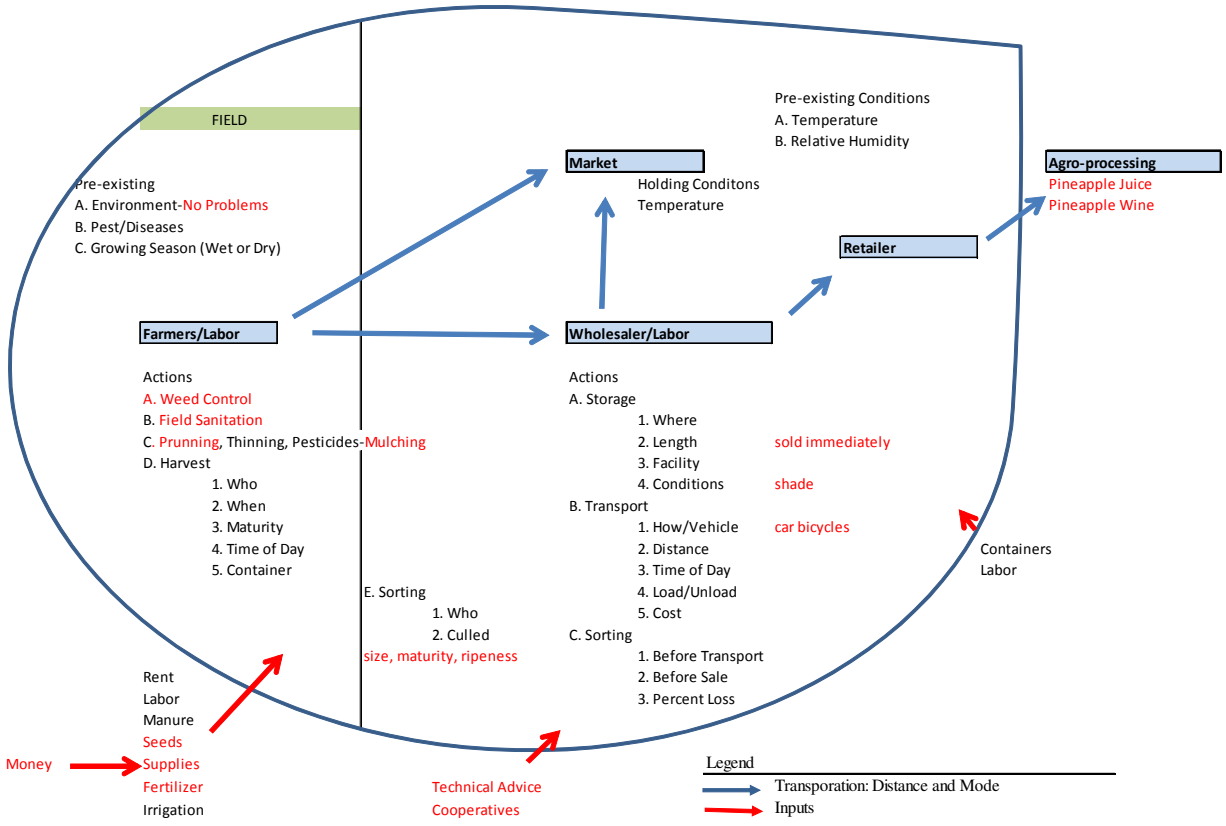

Figure 4. Postharvest Handling System for Pineapples. Figure 4 is a variation of the generalized postharvest handling system. This specific figure displays the postharvest handling system for pineapples. The variation between the generalized system and the specific system for pineapples is noted in italics.

Figure 4 is a variation of the generalized model modified for a specific commodity, pineapples. Those items in italics deal specifically with the pineapple postharvest handling system. The pineapple postharvest handling system was found to include additional inputs of technical advice and cooperatives. Technical advice was provided by Oxfam and Rural Agricultural Developmental Authority (RADA). An extension worker describes the goal of Oxfam (P,63,J) as "Oxfam: to give training to farm to increase production/processing of pineapple" RADA also provided technical advice as described by (P,69,K) "Technical Advice and Training by RADA".

Another interviewee (P,67,K) also responded “RADA reduce price of fertilizer for farmers.” The technical advice provided to farmers gives them information and examples of how to grow, harvest, and treat pineapples.

The postharvest handling system is also influenced by the presence of cooperatives. The cooperatives in sub-Saharan Africa helped producers to market pineapples better. Interviewee (P,63,L) described cooperative benefits as “They facilitate producers to market with they grow, sell at a price to ensure profit.” Pineapples are sold at higher prices when items are collected from individual farmers and sold together allowing the cooperative to be more competitive, (P,69,L) explains that cooperatives “collect produce for good price at market.” The marketing benefit of cooperatives ensures farmers a more stable price for pineapples, in turn, influencing all aspects of the postharvest system that rely on available money.

On the left side of the teardrop shape, pre-existing conditions have reduced importance in the pineapple postharvest handling system. The differences in the wet and dry season have no impact on growing conditions. The only impact of the wet and dry season is a modification of storage conditions as explained by, (P,72,CO) “Rainy season, store up to 2 weeks. Dry season they sell it immediately.”

Outside of the closed teardrop at the final unit operation, Agro-processing, the pineapple postharvest handling system is unique. Two agro-processing industries exist of pineapples. Both pineapple juice and pineapple wine are produced in sub-Saharan Africa. One processer was describing the steps from harvest to wine production (P,76,CO) as, “Fruits transported to factory in trucks, wine packaged in bottles, bottles to wholesalers in trucks.” Wine and juice processing are value-added processed that can utilize culled produce from other markets. However, none of the farmers or retail individual interviewed were utilizing their culled produce in a secondary

market for juice or wine production. Inside as described by (P,29,BG) as “Eaten at home, given to cattle or left in the field.” There is potential for individuals within the postharvest handling system to reduce postharvest loss by sorting and marketing produce to agro-processing within the market.

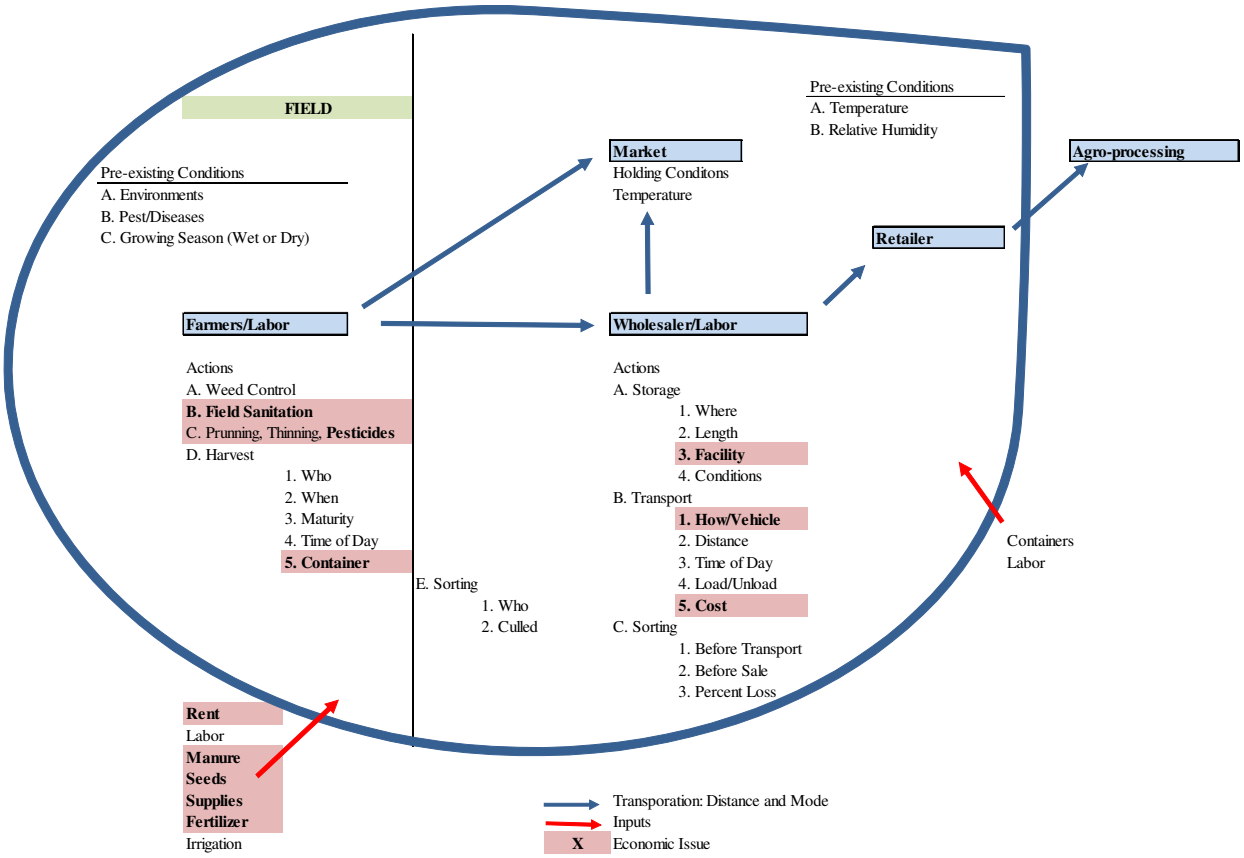

Figure 5. Areas of Economic Concerns in Postharvest Handling System. The economic factors in the postharvest handling system are shown in Figure 5. The items highlighted in red indicate items that are of importance both economically and with regard to postharvest loss and fruit and vegetable quality.

Figure 5 is a variation of the generalized model that highlights areas involving economic issues. It is worthwhile to note that while not explicitly stated on the model the entire postharvest handling system has an economic impact. Postharvest treatments can increase or decrease the quality at each stage in the postharvest handling system. The resulting increases or decreases in quality impact the selling price, value, and profits of each commodity. Additionally, some

postharvest activities require investments either short term investments for supplies and long term investments for capital goods. The specific areas of economic concern in the postharvest handling system are identified in Figure 5 by the highlighted blocks.

In the inputs section of the model, money is a significant economic issue. Even if, quality supplies are available, farmers must have the needed cash to purchase items. One interviewee (T,6,X) explains her purchases "Adequate supplies when she has the money, money is a limiting factor." A pineapple grower also recognized that purchases only occur when money is available (P,51,X) discusses the availability of planting materials "They are available but they can only buy them when they have money."

At the Farmers/Labor step in the postharvest handling system, notable expenses were reported for pre-harvest treatments. One tomato farmer (T,8,AR) reported costs of "7600 Fertilizer, 4000 Pesticides." The cost was reported in Rwandan franc. The significance of the investment is shown when comparing the cost of fertilizer and pesticides to the cost of inputs and labor by (T,8,AO) of "400 Inputs, 3600 Labor." A pineapple farmer quantified the pre-harvest practice of mulching (P,66,AR)" It is clear that individuals are willing to make significant investments if there is a perceived benefit from the associated cost.

When considering the Wholesaler/Labor step transportation and storage were areas of economic concern. The storage and transportation method by interviewees appears to be related to economic ability. Transportation using trucks or cars requires a larger initial investment compared to transportation by bicycle or on foot. The purchase of a car or truck requires a capital investment; however, the possibility of renting transportation equipment could provide new opportunities. Individual farmers and traders report transporting items on foot or by walking. A market intermediary (B,31,BL) reported that bananas were transported on "head or

bicycle." Whereas, wholesalers of bananas reported use of vehicles, cars, taxis, or trucks, to transport bananas, with (B,46,BL) describing the mode of transport as "a mini truck." As both the distance and quantity of items being transported increases so do the prevalence of vehicles used in transport.

Investing in commodity specific storage facilities is a long-term investment. There must be sufficient funds to build the structure. Additionally, the farmer must commit to continue producing the commodity for an extended period of time. Very few interviewees reported storage facilitates designated for fruit and vegetable storage. One example of a storage facility currently being used was from (T,12,BJ), "In wooden baskets with banana leaves on the bottom and polyethylene bag on the surface." Another interviewee reported storage of pineapples in the house (P,42,BJ) with no other treatment other than "lay them on the floor." The lack of appropriate storage facilities is an economic concern not only because of the cost of constructing appropriate storage facilities but also because of postharvest loss and profit loss resulting from improper storage of fresh fruits and vegetables.

It is surprising that labor was not identified as an economic concern. Within the answers of the producers interviewed, the majority of responses indicated that they or their families were the source of labor. There was no limit to available labor due to economic reasons.

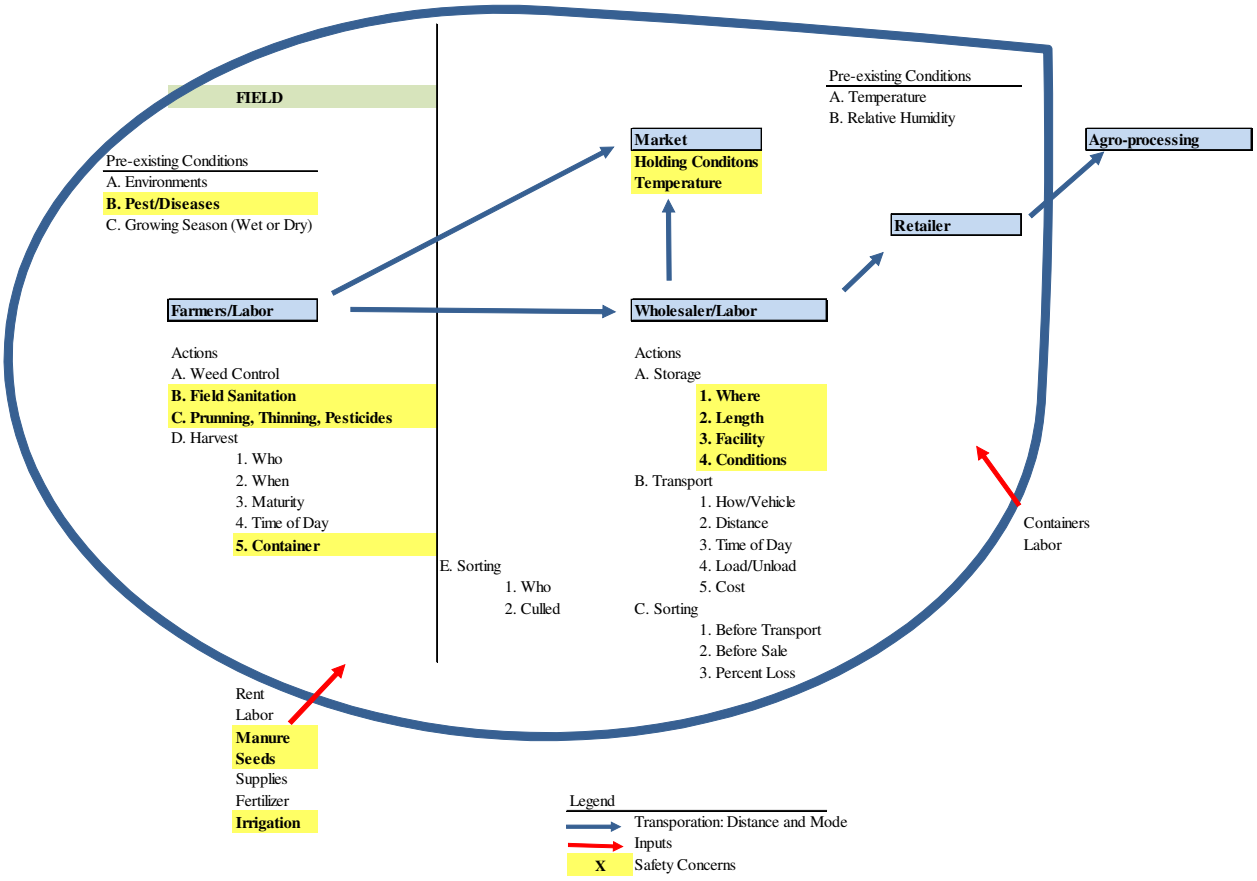

Figure 6. Food Safety Concerns in Postharvest Handling System. Figure 6 displays steps in the postharvest handling system that need to be controlled in order to account for the microbiological safety of the products.

Figure 6 is a variation of the generalized model. Figure 6 identifies unit operations where food safety is an issue and where change could prevent these issues. The identified areas are highlighted in the model. Good Agricultural Practices (GAP) and general food safety knowledge was used to identify areas based off of the interviewee's responses.

Within the inputs section of the model containers, manure, seeds, and irrigation were identified as areas of concern. For example, irrigation practices are a step where harmful microorganisms can be introduced to fresh fruits and vegetables. Farmers are aware of this issue as explained by (T,22,AC) agreeing that irrigation is practiced "Yes, but bad water is used." Other farmers practice irrigation along with other pre-harvest practices. Applying manure to

fields can be a potential food safety issue. One farmer (B,28,AC) describes their pre-harvest practices to be “mulching, irrigation, fertilization (by manure) maintain field sanitization.” While these practices can increase the quality of the fruit, there must be controls to account for microbiological contamination from irrigation water and manure.

Within the Farmers/Labor section of the postharvest handling system, the containers used during harvest and storage are concerns. Whether or not the container has previously been contaminated, and if any sanitization methods have since occurred is important. The storage containers continue to be a concern throughout the system. Plastic buckets and bins can be sanitized easier than plastic bags or wooden boxes. Many interviewees responded that plastic containers were used for tomato transport, such as (T,5,AX), who reported that “plastic basins” were used during harvest. Whereas, the responses of those individuals involved in pineapple production reported use of wooden boxes: (P,43,AX) reported that “wooden baskets” were used during harvest. Prior to analyzing any potential food safety risks from the use of containers the specific containers used in each system need to be identified and proper sanitation procedures determined.

Within the Wholesaler/Labor step, the storage conditions of fresh fruits and vegetables are important when evaluating food safety issues. Not only the temperature and relative humidity, but the facilities where the fruits and vegetables are stored are important. One wholesaler (P,60,BJ) presents storages practices as “In a room without other facilities no package, room 27 C for max 3 days.” Storage of fresh fruits and vegetables without any type of barriers is an issue as these conditions could allow for potential contaminations by pests and rodents.

The above food safety issues were identified through areas identified by interviewee's responses. Some areas of concern including containers and storage facilities were justified due to a lack of response and acknowledgment by the interviewees of the potential issues with their current practices. Rather than an expressed concern by interviewees a lack of concern of specific practices resulted in the identification of the issue.

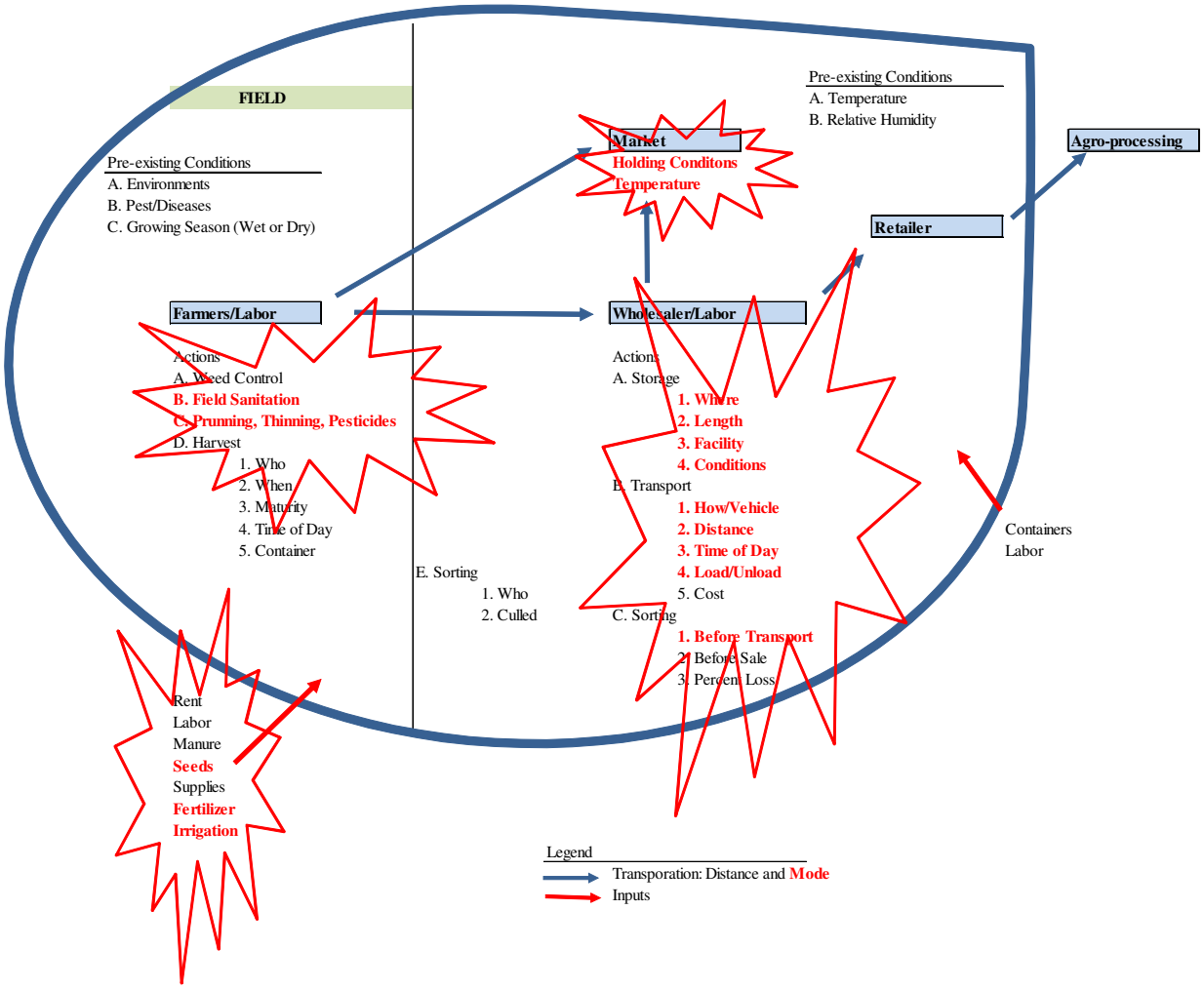

Figure 7. Overall Concerns in Postharvest Handling System. The starbursts shown in Figure 7 indicate the main areas of overall concern of the postharvest handling system.

Figure 7 is the generalized model shown in Figure 3 with the addition of starburst indicating the overarching areas of concern in the entire system. All previous models were analyzed, and the most common areas of concern were considered. Areas of common concern

and areas where limited resources and simple changes could have the most impact on the postharvest systems were identified. Within the starburst area, the items in bold are the suggested areas for immediate changes. For example, harvests were not identified as a main concern since most interviewees knew that the best time to harvest was not during the peak of the day and were aware that proper maturity should be considered when harvesting. However, changes in storage conditions along with transportation methods would be beneficial.

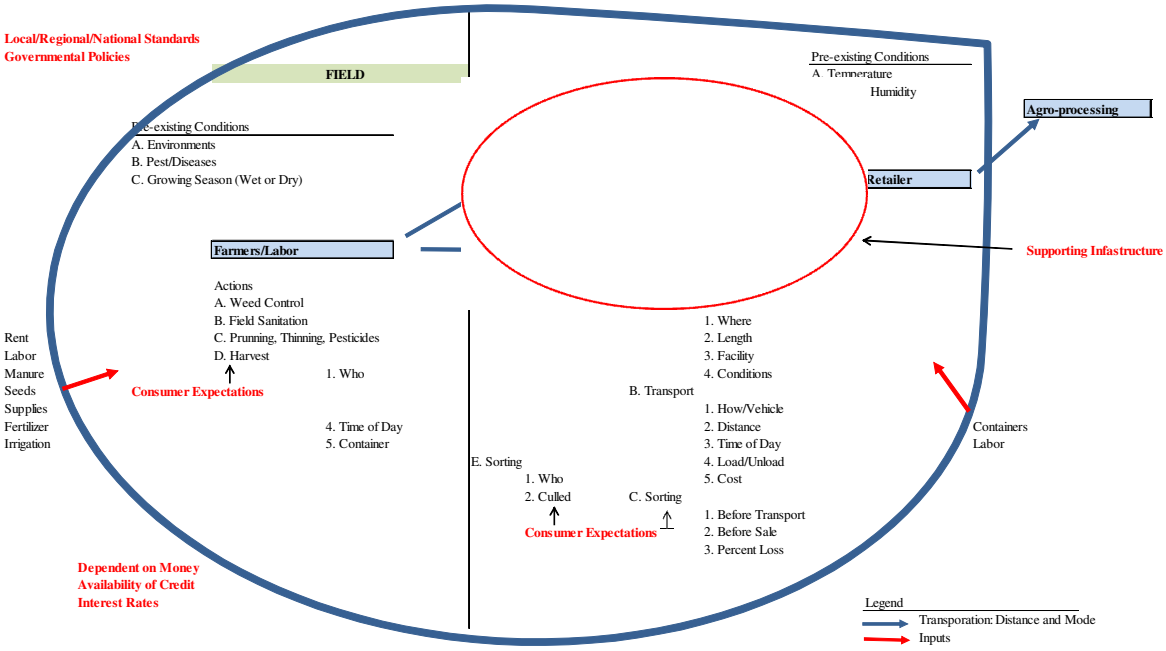

Figure 8. Influencing Factors in Postharvest Handling Systems. Figure 8 displays outside factors that influence the actions within the postharvest handling system including customer expectations, supporting infrastructure, standards and governmental regulations, and availability of credit.

Figure 8 shows the generalized model with the addition of influencing factors. Influencing factors were determined to be local/regional/national standards, governmental policies, dependence on money, availability of credit, interest rates, consumer expectations, and supporting infrastructure. These factors affect the postharvest handling systems because they often influence the systems and influence the decisions that producers and marketers make. The

system must function within the guidelines of these factors. For example, if consumers at the market are only willing to purchase fully mature items then farmers must either harvest at full maturity or store the items until they reach the ideal stage for consumer. Decisions and actions that occur in the postharvest handling system are influenced by these factors.

Commodity systems are unique because each system can only account for the impact of local and regional standards along with governmental policies for one location. There can be distinct differences on whether or not a system allows for the use of credit opposed to depending solely on liquid assets. Even if credit is available the interest rates effect whether or not credit can be used to purchases. The availability of credit allows for the purchase of adequate supplies and investments to capital to increase efficiency for the system.

Additionally, the expectation of the purchaser or consumer influence decisions made throughout the system. For example if there is only a market of one maturity, any items past that maturity will need to be sorted and culled unless a secondary market can be identified. The access to markets is limited by supporting infrastructure including everything from phone lines for communication to road conditions. The locations and functionality of available markets is another example of supporting infrastructure's impact on the postharvest handling system.

Discussion

Analysis of the postharvest handling system in sub-Saharan Africa and creation of the models yielded results similar to those of previously published literature. Wilson (1973) identified four major factors that influence the framework of a commodity system: (1) national goals and policies, (2) institutional environment, (3) structure of the commodity system, (4) coordinating linkages. Systems analysis using the CSAM acknowledges the role of structure of the commodity system as reported by Wilson number (3). Additionally, the results from

analyzing the postharvest handling systems recognize the importance of linkages within the system. Specifically the road and transportation linkages were recognized to be a factor influencing the postharvest handling system.

The containers as noted by (T,12,BJ) used for storage and transportation were identified as critical steps in reducing postharvest loss and for controlling food safety issues. Literature supports the importance in packaging choices since this is the final step where technology can be applied with regard to the specific fruit or vegetable. Additionally choosing transportation with regard to the specific commodity being transported is important (Shewfelt and Prussia, 2009). However, analysis of the postharvest system in Rwanda showed that the method of transportation was chosen solely on availability rather than appropriateness as reported by (B,31,BL). Therefore implementing postharvest technology at the packaging and transportation stages has a promise of significant impact in the reduction of losses.

The initial postharvest technologies suggested were the result of a 2011 trip to Rwanda. Suggestions to the overall postharvest handling system included shade; tables for sorting and packaging; quality evaluation; clean water for washing of fresh items; improved packages; simple cooling techniques; simple processing methods; and information about marketing and cost benefit analysis of new postharvest processes.

The steps were implementation of new postharvest technologies should occur were: cooling, sorting, packaging, transportation, shipping containers, marketing, food safety, and processing.

Conclusions and Recommendations

Analysis of the Data Collection Worksheets and CSAM Questionnaires resulted in two areas of concern within the postharvest handling system. The two areas identified were farmer-specific concerns and economic concerns.

The category of farmer-specific concerns includes the following:

a. Adequacy and availability of supplies
b. Preharvest practices including pesticides, irrigation, and fertilization
c. The impact of the rainy season and of sunburn on practices and quality
d. Harvesting methods, postharvest practices, and maturity of items at harvest
e. Grading, sorting, inspection practices and use of culled product
f. Storage methods and location
g. Transportation distance, conditions, and vehicles
h. Availability and accessibility to credit

The category of economic concerns includes the following:

a. Production cost
b. Economic impact of delays
c. Marketing costs
d. Variations in supply and demand of retail markets
e. Availability and accessibility to credit through cooperatives

Appropriate postharvest solutions were identified to address farmer-specific concerns and economic concerns. To overcome postharvest loss from sun exposure the use of light cloth covers, and utilization of the area underneath the overhangs of buildings should be used. Cooling methods could be introduced through the use of shade, night air ventilation, or zero

energy brick coolers. During the packaging step care should be used when handling the produce and buckets or plastic crates should be used. If woven baskets are used the weaving should face away from the produce. Lining buckets or crates can help to cushion the produce from vibrations. When placing a large amount of produce in the same container vents should be used to allow heat from respiration to escape. Night harvesting might be considered where possible (Kitinoja and Kader, 2002).

The methods used to address postharvest loss in developing countries involve more than introducing appropriate and effective postharvest technologies. Just as other factors influence the postharvest handling system, factors can influence whether or not postharvest technologies can be successfully implemented. Socioeconomic factors including the marketing system, available transportation, available tools or materials, and governmental policies influence how new technologies are implemented and accepted (Kitinoja *et al.,* 2011). Development plans should account for specific socioeconomic factors and plan methods of implementation accommodating them. Development plans should include a learning stage followed by a communication stage. During the communication stage, all activities should be scheduled effectively so as to prevent bottlenecks. Finally, development plans need to include plans to connect the private sector to the system (LaGra, 1990). One way to introduce postharvest technologies into the community has been through the use of marketing cooperatives. These cooperatives allow for central collection points for fresh items, discounts from purchasing packaging material in bulk, available vehicles for proper transpiration, storage facilities, and bargaining as a larger selling unit (Kitinoja *et al.,* 2011).

Decreasing postharvest loss will continue to be an area of research. A reduction in postharvest loss would have widespread increases in income are the best solution to chronic

malnutrition in poor countries (Paarlberg, 2010). Future work in postharvest systems will involve increases in expansive and effective education within targeted countries and communities (Hodges *et al.*, 2011). Increasing the knowledge of postharvest technologies and modification of technologies to meet the changing needs of countries will be important (Kitinoja *et al.,* 2011). In addition to increasing small-stakeholder adaption improves to the infrastructure is necessary. Increasing the commitment to marketing cooperatives and investments in micro-credits could allow for new opportunities within the market. Integrating small farmers and communities into global value chains has the potential to create a more effective postharvest system (Hodges *et al.,* 2011). As governmental policies influence both the marketing and postharvest handling systems, policy changes can dramatically impact postharvest loss. When considering governmental policy decision, it should first be recognized that decisions are often made with incomplete and biased information (LaGra, 1990). However, the integration of cost-benefit analysis into policy discussion has the potential to support effective policy decisions and allocation of resources for introducing new postharvest technology.

Summary

Data from CSAM Questionnaires and Data Collection Worksheets was analyzed using a grounded theory approach to develop six models representing the postharvest handling system in Rwanda. Figure 3 serves as a generalized model of the postharvest system which was modified to recognize economic and food safety concerns. Utilizing a systems approach to evaluate the postharvest handling system allowed for the identification of areas which are in need of new postharvest technologies. Identified areas included: preharvest practices, harvesting methods, grading, sorting, inspection, storage locations, and most of the transportation. Additionally, there were other factors shown to influence postharvest loss within the country including availability

of supplies, use of culled items, access to credit, cost of production and marketing, and volatility of regional markets.

Subjectivity Statement

As the observer of the system, I am not completely subjective and have the following bias. I had no previous experience in food systems and postharvest handling prior to beginning this project. My interests tend towards food science processing rather than agricultural systems. My academic background is in food chemistry, food processing, and general food science. This process began with a very loose review of the literature. Academic literature regarding plant physiology, postharvest physiology, and postharvest practices was surveyed to provide background knowledge and helped influence my perspective. My opinion about commodity systems and postharvest handling has been heavily influenced through communications with professors and readings. I looked at multiple small-scale postharvest practices developed by Kader and Kitinoja (2002). My personal outlook is influenced by the concept that reducing postharvest loss could increase food availability and security in developing countries. My analysis is potentially biased to look for opportunities to where small-scale postharvest technology can have a significant impact.

I worked closely with my major professor as a means to gather different perspective and question my interpretation of the model. Utilizing grounded theory helped to analyze the data which had been collected using a systems approach. Additionally, the development of the models and overall conclusions were presented to a group of non food scientist who have very little bias towards postharvest systems and postharvest technology and came with less subjectivity.

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CHAPTER 3

AID FOR TRADE INITIATIVE

Introduction

A global marketplace is thought to be the most beneficial when considering the good of all nations. All countries from small developing countries to large superpowers must be trading internationally to generate the maximum possible economic benefits from global trade. The recent economic crisis is an example of diversified economies exhibiting stability. A belief exists that diversifying economies overcome crisis due to multiple trade markets (Hoekman and Wilson, 2010). As global trade increases, buyers and sellers gain access to new markets and increased demands (Gucht, 2013). It is clear that trade liberalization can bring economic benefits. However, the benefits from liberalized trade are conditional to a country having access and the infrastructure to connect domestic and regional markets to the global market. The regulatory environments within the countries must also be favorable to trade (OECD, 2013b).

Transitioning to liberalized trade can be more difficult for countries concerned about losing tariff revenue and immediate adjustment costs. In developing countries several hurdles must be overcome before economic growth occurs from trade liberalization. Hurdles to be addressed include the country's infrastructure or lack of infrastructure, unavailable institutions, and lack of knowledge about available markets. Infrastructure is important as ports, communication methods, and roads are necessary to connect producers to international markets. Additionally, institutions are needed to collect taxes, run customs, and establish standards. These institutions must be efficient and effective (Nielson, 2005).

Adjusting to liberalized trade is important for countries because it is a pathway for sustainable economic growth. Trade practices that result in economic growth can function to alleviating poverty (Oom, 2013). Generally increased trade and expansion of trade will improve the overall quality of life. However, the connection between trade and poverty is unique to each location. Expansion of trade must extend to areas where the poor are living and are participants in the economy to impact poverty (OECD, 2013b). Many countries are recipients of aid and international assistance. Development aid is given to relieve poverty and encourage economic growth. Economic growth is an essential component of all development plans for addressing poverty. Commonly international aid assistance is linked with strategies for development. The donor country or organization typically establishes development plans that run parallel to development aid.

Aid for Trade

AfT is the main way that least developed countries are supported through a period of adjustment to multilateral trade rules (International Trade Centre). AfT is financing that flows from rich countries to poorer countries with the goal of enhancing a global trade system (Stiglitz *et al*., 2006). The AfT Initiative empowers, "developing countries, particularly least-developed countries to build supply side capacity and trade related infrastructure that they need to assist them in benefiting from World Trade Organization (WTO) agreements and more broadly to expand their trade," (International Trade Centre). AfT includes programs that help workers, communities, or manufacturers adjust to new trade policies or meet new terms of trade (Hoekman and Wilson, 2010).

In order to receive AfT, developing countries must identify a need for technical assistance and prioritize that need in development plans (International Trade Centre). Those

involved in AfT allocations include the governments receiving aid, non-governmental organizations, bi-lateral donors, multilateral donors, and regional organizations. The AfT Initiative also considers policy reform, projects to reduce poverty, and projects aimed at increasing the global standard of living as AfT (OECD, 2013a). AfT supports the creation of trade policies and efforts to reform country regulations. The coordination of a country standards and regulations to match those of international standards is an example of AfT. Capacity building activities of AfT include seeking to increase and diversify the exports of a country. Additionally, infrastructure related to trade includes roads, ports, communication networks, and reliable electricity. Trade related adjustments include programs to reduce traffic and allocations to cover the costs incurred when adjusting to new trade policies (Hoekman and Wilson, 2010).

Prior to formally established and recognized definitions, Nielson (2005) defined AfT as five activities: technical assistance, capacity building, institutional reform, infrastructure, and assistance with adjustment costs. Formal definitions and categories of AfT followed. The OECD established the following categories of AfT, technical assistance for trade policy and regulations, productive capacity building, trade- related infrastructure, trade related adjustments. The OECD's categorization of AfT is very encompassing and includes all aid that supports aid specifically pertaining to trade. The OECD does not just consider AfT projects. Overstatement of AfT can result from this categorization. In the OECD's categorization of projects, all infrastructure projects except sanitization and water infrastructure are considered trade related (Hoekman and Wilson, 2010). The WTO AfT Task Force established two broad categories of aid. The two categories are Trade Related Assistance, and Wider AfT. Trade policy and regulations and trade development are found under the Trade Related Assistance category. Wider

AfT includes trade related infrastructure, building productive capacity, trade-related adjustments, and other trade-related needs.

History of Aid for Trade

Through 2002, AfT was in a period of decline. Historically any developmental aid given to support trade was given for mutually beneficial with the donor country sourcing goods or services. After 2002, investments in AfT rose most likely in coordination with the initiation of the Doha Development Round. The Doha round stressed the important of expanding global trade (Hoekman and Wilson, 2010). The Doha Development Round is the round of trade negotiations for the World Trade Organization that is currently active. It began with the Fourth Ministerial Conference in Doha, Qatar, in November, 2001 and continued through Ministerial Meetings in 2003 and 2005 in Cancun and Hong Kong respectively. Additional Doha round negotiations occurred in Paris, Potsdam, and in Geneva multiple times. In 2008 at the meeting in Geneva, negations reached a breaking point over agricultural import issues. The objectives of the Doha Development Round are to lower trade barriers and increase the amount of overall global trade. Major issues were the result of contributions by the European Union and The United States (Fergusson, 2008).

The World Bank and the International Monetary Fund concluded that even though developing countries were participating in the Doha round of negotiations, developing countries would not automatically gain from the trade liberalization. Instead, countries would have significant costs to cover translational adjustments. International aid should be increased to allow these countries to overcome constraints restricting their participation in new trade opportunities. They suggested that that AfT needed to be an essential part of Doha negations (Development Committee 2005).

At the WTO Ministerial Conference of Hong Kong in 2005, the AfT Initiative was created. The AfT Initiative supports both trade related assistance and Wider AfT. Wider AfT supports the overall economic ability of a country including investments in infrastructure. Trade-related assistance helps countries to adjust and implement new trade policies (European Commission, 2009). In 2005 G-7 Finance Ministers requested proposals of how to help developing countries overcome costs and take advantage of markets created through trade liberalization. At the G-8 Summit in 2005, three proposals were submitted by the World Bank and International Monetary Fund. The proposals were approved and implemented (Nielson, 2005). AfT has become a focus of the international community; with the goal of helping developing countries adjust to trade liberalization along with reducing poverty through economic growth (OECD, 2013a).

Following the WTO Ministerial Conference in 2005, a task force was established by the WTO with the goal of *operationalizing* AfT in 2006. The Task Force had thirteen country members and was given specific objectives. The objectives included determining the scope of AfT, identification of outstanding needs or gaps, determination of the kind delivery mechanisms needed to address gaps. The conclusions of the Task Force were to strengthen the connections between countries requesting AfT and the responses of other nations. The needs of regional areas and opportunities for regional implementation of AfT were also suggested (Raihan, 2007).

There is renewed commitment to the AfT in both the WTO and the Group of 8. In 2009 The G-20 summit stated continued supported of their AfT commitments (Hoekman and Wilson, 2010). To regulate, monitor, and evaluate AfT projects, the WTO and OECD created a monitoring and evaluating framework (OECD, 2013a). The Enhanced Integrated Framework (EIF) was founded in 1997 with the support of the WTO, World Bank, and ITC. The EIF is a

program used to help monitor and assess all trade related assistance given to lease developed countries (Raihan, 2007).

There is no organization or financial group that single handily coordinates the delivery of AfT. AfT is supplied to individual countries through developmental agencies or bilateral donors. Allocating aid for specific countries ensures that aid will target the needs the government has prioritized. A restriction of allocating aid in this method is limiting those who can act in the distribution and evaluation of aid given. Investments in AfT have risen with an increase in trade related investments and projects by the World Bank Group. In the country assistance strategies of the World Bank trade was an identified priority and assistance programs focusing on trade were recognized (Hoekman and Wilson, 2010).

Functionality of Aid for Trade

AfT brings economic development and expands overall trade; therefore, all nations involved in global trade reap the benefits of AfT. AfT impacts citizens in developing nations along with the citizens of the richest developed countries. Every nation profits from trade (Hoekman and Wilson, 2010). AfT, like any type of aid, results in real currency appreciation. However, unlike other forms of aid, AfT focuses on liberalization of trade, trade facilitation, and the competitiveness of the country within a global market (Nielson, 2005). The negative repercussions of aid can be avoided when the trade capacity of countries is simultaneously increased. Dutch disease is a common problem resulting from negative competiveness of countries steaming from increased aid. Dutch disease was named after the Netherlands, and the currency appreciation that resulted after the discovery of natural gas. A country's currency can appreciate from a large influx of foreign currency. The influx of currency could be the result of increased exports or aid given to the country. The competitiveness of a country is negatively

affected as a result of the currency appreciation. The rising value of the currency decreases the competitiveness of products and services from the country.

In theory demand for goods will remain even once monetary AfTis withdrawn. Even more, AfT can help establish countries to where investments in the country continue in an entirely free market with no AfT allocations. AfT increases the productivity of firms within a country while also lowering trade costs. AfT focuses on better infrastructure and better access to low cost, quality services (Hoekman *et al*., 2010). Within countries, AfT does not favor or provide advantages to specific industries or products. Instead, AfT benefits all industries through improving infrastructure, administration policy, trade policy, and skill development (Cali and te Velde, 2008). Investments in infrastructure are combined with aid that reduces the cost of trade. Competition between transportation providers and modified border policies can reduce the cost of trading (Hoekman and Wilson, 2010).

AfT also functions to aid in policy changes. Policy changes should focus on increasing the competitiveness and work to facilitate the entry of services products to a country. Service products utilizing few capital investments should be of primary focus. Regulation of service inputs is important because these inputs are a significant portion of production costs. Methods of increasing the number of available options; increasing efficiency; and reducing the cost of services can significantly change the competitiveness of producer firms (Hoekman and Wilson, 2010). The long term implication of new policies must be evaluated to determine whether changes would result in increased operational cost or act as a hindrance to innovation within a country.

Effective AfT starts with proper distribution of resources and aid available. It is important that programs target the neediest least developed countries and consider the use of regional

programs to increase the impact to aid (Gucht, 2013). Several organizations have roles in AfT allocation. The role of the WTO in AfT is to encourage the flow of aid allocations from bilateral donors to regional donors. The WTO supports the request for aid from individual countries along with encouraging countries to include trade goals and trade development plans within the overall national development goal. The WTO also supports the monitoring and evaluation of AfT (WTO, 2013)

The Enhanced Integrated Framework (EIF) is a program that assists in AfT allocations. The program is funded through trust backed by OECD donors (International Trade Centre). The EIF serves as a source of AfT resources and works to better understand and map the needs of LDCs. The EIF is a model of partnerships between many different organizations, donors, developmental agencies, and banks. Unique to the EIF is the emphasis placed on developing countries owning developmental strategies on a local level (European Commission, 2012).

The International Trade Centre is multilateral team created to provide technical assistance for trade related issues. Technical assistance is provided in three areas: business advice, private sector input, policy development, and solutions to the supply-side development issues. The use of micro-enterprises and small enterprises is suggested to work in the AfT framework. The ITC partners with the WTO and the United Nations Conference on Trade and Development. The ITC also encourages the use of micro-enterprises and small enterprises.

Aid for Trade Justification

Trade reforms, specifically those seeking to open more global markets threaten developing countries. AfT increases support for these reforms and help to appease protectionism movements found within developing countries. AfT provides the additional support that countries need to become competitive in the globalized trade market. The adjustment to

liberalized trade requires the integration of a country into regional and global markets. While barriers to trade have been reduced on paper, many developing countries are not benefiting from the opportunities result from trade liberalization (Hoekman and Wilson, 2010). Developing countries need help to build trade related-capacity, which can include policies, infrastructure, and institutions (OECD, 2013b). Countries also need support in financing the higher cost of trading.

Global trade is increasing, and while many previous trade barriers no longer exist, other barriers to trade flow must be considered. Better global trade requires that individual countries gain either competitive or comparative advantages by reducing the cost of trading. A global focus on trade reform and building trade capacity needed to minimize the cost of trading on the global market. Trade is needed to maintain industrial development; however, trade alone cannot create industrial development. Even if countries can participate in globalized trade the welfare gains from liberalized trade come with a cost (Stiglitz and Charlton, 2006).

Access to markets is hindered by inefficiencies within the country including customs, private sector relations, and governmental regulations. The differences in customs efficiency are apparent when comparing SSA and OECD customs practices. To clear customs between OECD countries involves five documents, ten days, and an average cost of 750 Euros per container. Whereas, to clear exports customs in SSA requires more documents, 35 days, and 1300 Euros. Imports require 44 days and 1500 euros per container for imports (Gucht, 2013). Infrastructure related to transportation can prevent small farmer from reaching international ports or even larger markets within a country. Increased production costs can result from insufficient storage facilities, poor electrical power, and water needs. Not considering physical infrastructure, the infrastructure within a country including supporting agencies can increase or decrease competitiveness of producers. Development organizations now recognize the need for donor

supported funding for public infrastructure to increase supply and capacity within LDCs (Stiglitz and Charlton, 2006).

Increasing the competitiveness of countries with low trade capacity can occur through AfT investments. AfT provides support for developing countries initially when support is needed to enter into the global trade arena. AfT increases diversification within countries and countries are introduced to new markets and potentially new products (Hoekman and Wilson, 2010). AfT allows for equal access of countries to industrial and agricultural goods. AfT promotes access through contributions to local institutions and to infrastructure development (Raihan, 2007). Economic growth can result from AfT through increased competiveness of developing countries resulting from lower production costs and increased productivity (Hoekman and Wilson, 2010). AfT covers the lost revenue on a macroeconomic scale including lost revenue from tariffs and the cost of reallocating labor within the country. Additionally, AfT finances the administrative changes and supply-side changes countries need to capture opportunities after multilateral trade (Prowse, 2005).

Distribution of Aid for Trade Allocations

The distribution of AfT occurs along a priority scale ranking countries' needs. The ranking of countries occurs through collaboration of aid donors, multilateral corporations, and the developing country with regard to trade performance and capacity (Thow and Priyardarshi, 2013). Exactly 93% of all AfT is allocated to low income countries. Regional development banks primarily devote allocations to low income countries. However, bilateral donors tend to devote less to low-income countries (Hoekman and Wilson, 2010). This difference in aid allocations is because some aid is given for the benefit of donor countries. In some cases, aid is given to countries to which the donor country already has strong ties (Osei *et al*., 2004). A study by

Gamberoni and Newfarmer (2009) found that countries determined to be in need of AfT were receiving more assistance than countries not found to be in need of aid. Martinez and Wilson (2009) also concluded that countries with the greatest need for aid were receiving higher levels of AfT.

Since the official launch of the AfT Initiative in 2005, $200 billion USD has been given as AfT funding. Funding directly given to LDCs since 2005 has totaled more than $60 billion USD (Lamy, 2013). Allocations of AfT can be given to a variety of projects or categories of AfT. Over half of all AfT is given to infrastructure projects (OECD-WTO, 2009). The largest portions of AfT are for the development of infrastructure and to build productive capacity. Trends in aid donations include fewer allocations of aid towards infrastructure, including decreasing amounts to energy generation and transportation. Increases in aid given to productive capacity were shown in agricultural and banking sectors. The increases in aid happened in parallel to the fiscal crisis and issues involving the global food supply (OECD-WTO, 2012). AfT allocated to agricultural projects rarely supports food crop production.

In a review of United Nations Development Program, 85 percent of the development programs were found to include a section related to trade. Additionally, of the programs involving trade, 72 percent make a correlation between trade policy and poverty experienced within the region. This situation provides recognition for the link between trade and the reduction of poverty levels (Kosack, 2008).

Many donor countries have recognized the importance of AfT. The United States provides assistance to build trade capacity under three names: “trade capacity building assistance,” “Aid for Trade,” and “trade-related assistance,” all of this assistance falls under the foreign assistance strategy related to economic growth. Additionally, the United States gives

training and technical assistance to help countries compete and make decisions (Office of the United States Trade Representative). The Swedish Aid for Trade program allocates aid to support and integrate LDCs into the trading systems by taking advantage of multilateral trade. In a year period from 2010 to 2011 Sweden double the amount of assistance provided as AfT, demonstrating continued support for the AfT program (Oom, 2013). In 2012, the Irish Department of Foreign Affairs and Trade launched an Africa Strategy. The development of the new strategy promoted investments within Africa that would be beneficial to Ireland and individual African countries (Costello, 2013). The new Strategy is important because Ireland already has strong relationships between the private sector and West and South Africa. It is estimated that over thirty thousand jobs have resulted from Irish connections in Africa. Traidlinks, a not for profit Irish company, present in Uganda provides mentorship for businesses, as well as, a program to support exports and linkages between businesses in Ireland and Uganda (Costello, 2013). Additionally, Ireland has launched the Africa Agri-Food Development Fund working with Kenya and Tanzania. The program has resulted in agri-food companies visiting East Africa to determine investment and market opportunities (Costello, 2013). However, Ireland is not taking these actions without the input of the African countries. In October, representatives from 23 countries came to Ireland to discuss investment and trade opportunities that could increase employment (Costello, 2013).

Reviews of Aid for Trade

How aid influences a country is affected by many factors including economic policies, regulations, and country specific conditions. Not all trade growth is measurable, and it is difficult to link the given aid to a specific area of growth (Bourguigon and Sundberg, 2007). Evaluation of AfT has certain limitations including an overall lack of data on the subject. Very little baseline

data exist to measure the impact of aid against, and there is not a way to extract the impact of AfT programs from other programs involving human welfare. In a way to address these limitations, reviews have focused on the impact of aid on an aggregate level evaluating improvements in trade levels or increases in trade capacity (Hoekaman and Wilson, 2010).

Evaluating the effectiveness of aid is a challenging and ever improving process. Determining the effect of aid is complicated because development projects do not always have clearly stated and measurable objectives. It is difficult to determine the ultimate success of a project. Methods to evaluate the impact of AfT could be improved by looking at the impact of different categories of trade and the resulting impact (Cali and te Velde, 2011).

Hoekman and Wilson (2010) present initial areas to review in order to determine the effectiveness of aid. Areas of evaluation of AfT include the following:

- Is aid allocated to countries in need?
- Are programs expanding trade and reducing poverty?
- Are programs meeting stated goals?
- Do outcomes differ in situations without the project interventions?

The WTO and OCED function to monitor AfT. The amount of donated aid is tracked at the individual country, regional, and global level. Additionally, the quality and effectiveness of AfT is monitored through surveys completed by donating and receiving countries. Reviews of case studies occur to enable a better understanding of the effects of AfT on a global scale. The review of case studies allows for recognition of the other non economic effects of AfT. For example, increases in human capacity along with institutional capacity are not easily identifiable without review of specific case studies (OECD-WTO, 2012). The second global review of AfT concluded with the following six areas of focus for the AfT Initiative:

- Stronger regional AfT programs
- Increased monitoring and evaluation of AfT impact
- Political support and commitment for governmental policy reform
- Acknowledgment of the role of South-South cooperation
- Recognition of the connection between the hardware and software of trade
- Reduced cost of trading

The Global Reviews of AfT in 2007 and 2009 show that AfT is making progress and becoming more effective (International Trade Centre). The Third Global Review of Aid in 2011 considered many individuals cases before conclusions were made. 269 cases were analyzed, and 140 self-assessments from countries, donors and agencies were collected (OECD, 2013a).

The OECD reviewed evaluations of trade related projects in 2006. In the OECD review, half of the evaluations showed that programs raised awareness of trade and increased knowledge of trade within the region. These programs also resulted in an increased dialogue regarding trade. However, there were very weak connections between the projects and poverty reductions. Many projects suffered from coordination issues involving donors and experts in the field (OECD, 2006). An evaluation group from the World Bank in 2006 found that trade related adjustment loans preformed better than other loans by eight percent. However, investment loans that including trade infrastructure were less successful than other investment loans. (Independent Evaluation Group, 2006). Considering projects, AfT projects performed better than projects without an AfT trade component (World Bank, 2009).

The effects of aid can be analyzed with regard to the type of aid given. There is a difference in aid given for humanitarian efforts and aid that is given to drive trade policy changes. Additionally, there must be a consideration of the impact of Dutch disease. These two

responses to aid could negate any potential positive results from AfT (Hoekman and Wilson, 2010). Aid given to infrastructure should reduce the impact of Dutch disease because the aid is used for productive projects rather than is given to projects with productive uses rather than consumption projects. Differentiating the different types of AfT could help in evaluating the impact of AfT (Cali and te Velde, 2011). Methods to evaluate the impact of AfT could be improved by looking at the impact of different categories of aid.

Reviews of AfT in academic literature show a connection between AfT and an increase in exports and investments within a country. Econometric analysis identified a positive correlation between AfT allocations and a country's economic performance (Basnette *et al*., 2012). However, not all AfT results in positive economic growth. The results from AfT allocations vary as a result of the type of project, the country's income level, geographic location, and to which sector of industry the allocation was directed (Basnett *et al*., 2012).

In 2007, a review of 97 different studies determined that the impact of aid on the growth of nations was not significant (Doucouliagos and Paldam, 2007). A review of AfT data by Cali and te Velde (2009) found a positive correlation between AfT and trade expansion. Considering the categories of AfT, AfT facilitation was identified as a method of reducing the cost of trading. Additionally, aid for infrastructure was shown to increase exports. The initial analysis was conducted with a sample of 130 developing countries over a four-year period, and further work involved 100 developing countries over a five-year period. The impact on the cost of trading considered the role of AfT facilitation, and the impact of AfT policy and regulations. Positive increase in the level of exports was the result of aid given to economic infrastructure, whereas, aid for productive capacity had no recognizable effect. Aid given to trade facilitation decreases the cost of trade. A $390,000 USD allocation of aid reduced the cost of importing a 20 foot

container of goods by $82 USD. Aid given to infrastructure is shown to reduce the cost of trade more in SSA than in other locations. The reasoning was that a lack of infrastructure can be a barrier to economic growth and increased trade in SSA.

Review of AfT by categories was also completed by Helble, Mann, and Wilson (2009), high levels of marginal return were found for the AfT category of policy and regulation reform. Results estimate that for each US dollar given specifically for policy and regulatory reform 700 dollars of increased trade flow results. However, these results were presented with acknowledgment that diminishing returns would occur at some point. It was determined that AfT facilitations can reduce the cost of trading and increase in exports from a country.

Research done by Francois and Manchin (2008) has shown increased exports resulting from investments in hard infrastructure. Specific projects related to exporting goods were reviewed by Brenton and von Uexkull. Their review concluded that projects related to specific commodities have shown increased exports in those commodities. Higher levels of exports were achieved when the targeted commodities were significant export commodities. Programs were most successful when they focused on fixing a policy issue or a specific market failure preventing an export from being competitive in a global market (Brenton *et al*., 2009). The welfare of consumers also increases as a result of infrastructure investment (Abe and Wilson, 2009). Evaluation of AfT in sub-Saharan Africa shows that aid contributions equaling one percent of total GNP results in a third of a percentage point increase in the growth of the country (Gomanee *et al*., 2002).

Success in AfT programs is characterized by donor countries as increased export levels and diversification of the economy in the receiving countries. Additionally, donors are looking for increased trade levels, expansion of the economy, and reduction in poverty levels (OECD-

WTO, 2012). AfT has been determined to be most successful when the allocations are made in areas where the cost of trading can be reduced including infrastructure investments and improving value chains. Allocations of AfT that seek implementation at the regional level or at transitional steps have produced good results. Early recognition of constraints to investments and trade were fundamental to the success of AfT projects. Additionally, communication and coordination between multiple donors and aid recipients was essential in the AfT projects that worked. As with any project, it is necessary that expected results be reasonable and realistically achievable (Basnett *et al*., 2012).

Individual Cases of Aid for Trade Allocations

One of the earliest AfT projects was conducted in Vietnam through the World Bank. The project focused on building capacity, reforming customs practices and procedures, and creating more effective IT and communication (Nielson, 2005). Improvements in customs efficiency are a proven result from AfT. Reforming customs in Cameroon increased governmental revenue by 12 percent. In Haiti introducing electronic customs decreased release time for low-risk good by two days. Reform of custom practices in Ethiopia doubled the number of imports and exports while increasing revenue by 51% (Gucht, 2013).

In the 1980s in response to an economic crisis, Costa Rica opened their economy attracting foreign investments in agricultural and textiles. Costa Rica was traditionally been an exporter of two goods, coffee and bananas. In 1997, Intel invested in Costa Rica and established an assembly plant for microchips. Following Intel's actions many other foreign investments flowed into Costa Rica. Now, around 40 percent of the exports from Costa Rica have some linkage to a global value chain. Costa Rica has expanded from Intel chips to medical devices, aeronautical parts, automotive, and other electronic goods (Gonzalez, 2013). Seeking the success

of countries like Costa Rica, China, India, Brazil, and South Africa have all opened their economies to trade. Growth and economic development have followed in these countries (Gucht, 2013).

An example of aid directed towards a specific industry is Rwanda. Aid was given to improve the Rwanda coffee industry, and investments from NGO donors, private sector investments and allocations from the Rwandan government totaled 60 million dollars. Goals were to increase total exports of coffee and position Rwandan coffee as a specialty product. As a result of the investments many buyer/seller relationships have evolved and the production of coffee in Rwanda has increased. Cooperatives within Rwanda have been able to achieve "fair trade" status and the corresponding demand for such products. Additionally, the installation and accessibility of washing stations doubled farmer's income due to grading and sorting by quality (Nielson, 2005). Investments in infrastructure, technical training, and better availability of technology can help in reducing costs and improvements in trade (Thow and Priyadarshi, 2013).

Mongolia was traditionally an exporter of wool; however, exports and market share were declining in the 1990s and 2000s. The implementation of an Export Development Program in 2003 created a pattern of growth in wool exports (Hoekman and Wilson, 2010). Canada funded a project to train individuals in China about WTO marketing rules and food safety practices. Individuals trained included farmers, extension workers, and governmental employees (International Trade Centre). A project that enabled Sri Lanka to gain international recognition for accredited product testing laboratories was financed by the Swedish government. Because of this accreditation it is easier for Sri Lanka's exports to reach the markets of developed countries (Gucht, 2013).

Within Uganda, a program providing business management training for women entrepreneurs doubled the sales of participants and provided 500 jobs (OECD-WTO, 2012). Another project focused on the customs and border crossings between Zambia and Zimbabwe. Under previous conditions trucks endured a five-day delay when crossing the border. The establishment of one-stop posts on the border at Chirundu reduced the wait time to mere hours (Gucht, 2013). Modifications to the transit systems at the border of El Salvador and Honduras improved the transit time from over an hour to less than ten minutes. In Senegal, an AfT program focused on increasing the competitiveness and sustainability of agricultural practices in Senegal. Within a four year period, the exports from Senegal increased by over 70 percent and 85 new businesses were created (OECD-WTO, 2012). Increased competitiveness occurred in Mexico after AfT investments. It was difficult for poorer fisherman and farmers to comply with the food safety requirements of Europe. A project helped individuals understand and comply with food safety requirements allowing Mexico to benefit from the EU-Mexico Free Trade Agreement. This benefit is shown in the two-fold increase in honey, fish, and seafood exports (Gucht, 2013).

When considering Non-Communicable Diseases (NCDs), Thow and Priyadarshi (2013), identified AfT as a method of enhancing overall health in developing countries. The WTO, FAO, and World Bank acknowledge the increased production and export of fruits and vegetables could benefit countries from an economic and nutrition standpoint. There is the potential for collaboration between trade investments and the health sector for economic and NCD prevention via AfT allocation. The pathway of AfT was identified partially because of the increase of allocations of AfT during the current global financial crisis.

The rationale behind the collaboration between AfT and the reduction of NCDs is to overcome the challenges that exist in improving the quality and increasing the production of

fresh produce in developing nations. Addressing the same challenges would help to decrease postharvest loss. A lack of infrastructure for processing or transportation prevents many producers in developing countries from having access to international markets. Additionally, the sanitary and phytosanitary import standards for developed countries can limit the access developing countries have to this market. Through increasing the available supply of fresh fruits and vegetables dietary nutrition will increase, as well as, overall economic livelihood (Thow and Priyadarshi, 2013). The introduction of farmers to modern global supply chains will also benefit local communities. It is shown that farmers participating in global chains are also active in local markets (McCullough *et al*., 2008). The methods by which AfT could increase fruit and vegetable supply are through connecting producers to technical assistance, improving the connecting infrastructure between producers and regional markets, and supporting increased production and exports of agricultural products through supportive governmental policies (Thow and Priyadarshi, 2013).

Aid for Trade Progress

The development community has recognized the AfT initiative. Both donors and countries receiving AfT recognize the legitimacy of AfT programs (Gonzalez, 2013). Allocations to AfT have increased since 2005 due to the actions of donors and development agencies. In 2010, 25 billion € were invested in AfT projects. The 25 billion € investment was a 50 % increase from what was given in 2006. Of all official developmental aid given, a third is given as AfT (Gucht, 2013). Assurance that AfT is distributed effectively and that aid given is targeting national priorities has been essential in maintaining aid donations from countries (Hoekman and Wilson, 2010).

The effectiveness of AfT programs has increased. Increased effectiveness is a result of gathering support from governmental agencies in donor countries. Better evaluations and monitoring practices have allowed for better utilization of resource maximizing AfT contributions and creating tangible results (Gonzalez, 2013). Developing countries that entered the global market as a result of liberalization of trade have been moving towards industrialization driven by increased exports from their country (OECD-WTO, 2012). Current AfT allocations and future projects will most likely involve coordination between multiple countries or to be facilitated through development agencies. Sweden has been moving towards projects that involve or are funded by bi-lateral donors, multiple countries, Swedish institutions, research universities, and regional development banks. Increased recognition of the role the private sector plays in AfT has occurred.

Better methods for evaluating aid effectiveness are still needed. Methods should be built upon the framework developed by the OECD and WTO. Aid programs and projects should be evaluated with regard to whether trade capacities increased and whether the project impacted long term goals like those of the millennium development goals. Better methods of AfT delivery are needed. In the allocation and installation of AfT innovate practices and techniques should be used in the delivery of aid. Aid delivery should consider all sectors of the economy that trade influences. More sources of AfT and better implementation of effective aid should call upon the private sector involvement in AfT projects. Finally, the effect of aid on a country should be considered with respect to intellectual infrastructure, and the development of sustainable trade and development agendas (OECD, 2013a).

Additionally, there is a need for collective efforts to target countries most in need, specifically LDCs. These countries should be given trade preference and aid. Developing

countries are not lacking in entrepreneurs these entrepreneurs are lacking in opportunities. Trade can increase the opportunities present in the developing countries (Gucht, 2013). Methods to promote trade and increase investments are necessary to achieve levels of economic development needed to end global poverty. Focus must be given to responsible investments and programs that create sustainable employment (Costello, 2013). To increase the impact of AFT middle-income countries need to become more involved in AFT participating in transfers of knowledge, investments, and improving access to their markets. Private sectors should become more involved with AFT since private investors have the best knowledge of successful and unsuccessful strategies. Focus on improvements in policies within the countries could be helpful to increase the competitiveness of a country specifically at the individual firm level (Hoekman and Wilson, 2010).

Remaining Needs in Developing Countries

There is still a very real need for trade aid in developing countries. The global economic crisis increased the need for AfT allocations. AfT can increase the productivity of farmers living in developing countries. Increased productivity in developing nations can aid in recovering from the economic crisis and enable long-term economic development. Since long term commitments have been made, it is vital that existing AfT commitments are honored. Uninterrupted donations of aid need to continue to ensure countries benefit from AfT investments and recover from the economic crisis (Hoekman and Wilson, 2010).

Barriers to success exist for poor women and men in developing countries. Consideration should be given to the gender roles that exist within countries, and the impact of these roles has on trade. Understanding the link between poverty and trade could allow for the use of trade expansion to reduce poverty (Oom, 2013). In addition to gender roles, AfT has a future in the

helping to support smaller farmers in the export market. The current export market is moving towards vertical integration and is increasingly concerned with food safety, therefore; smaller farmers will need increased support to survive in the changing export market (Thow and Priyadarshi, 2013).

Global value chains can help to engage developing countries into global trade. A lack of natural resources or manufacturing ability no longer prevents a country from becoming part of production networks. Countries can find specific roles inside a value chain by performing specialized tasks. Participating in global value chains has the potential for creating new industries (Gonzalez, 2013). In the European Union, there is a view that regional economic integration needs to occur so that individuals can become competitive in a world market through the utilization of economies of scale (Gucht, 2013). More support for global value chains is apparent in the theme chosen for the Fourth Global Review of AfT was "Connecting to Value Chains."

A review program from the International Trade Centre in 2011 suggested a need for continued private sector support, increased application of regional development plans, and for more countries to include trade goals in their development plans. The AfT monitoring and evaluation programs were also identified as an area for improvement (International Trade Centre). The WTO Aid-for-Trade Work Programme for 2012-2013 identified the following five key areas of focus for the future of AfT:

- Resource mobilization
- Mainstreaming of trade into development plans and programs
- Regional trade integrations
- Private sector development
- Monitoring and evaluation of AfT

Continued Impact of Aid for Trade

Capitalizing on global value chains and participating in new trade patters provides a pathway for developing countries to enter into global trade. New AfT programs should support ways in which to connect developing countries with production networks and help establish the competitiveness of developing countries. Developing skills and building infrastructure can help increase competitiveness. Investments in infrastructure address a key issue in postharvest handling chains within developing countries. Working to establish appropriate and effective infrastructure and linkages not only help countries compete internationally but can also aid in reducing postharvest loss locally. Additionally, there are opportunities for developing countries to enter into global value chains as a source of economic growth and expansion (Gonzalez, 2013).

Investments given to countries in the form of AfT allocations have the potential to reduce postharvest loss. The same mechanisms that make global trade more effective in developing countries also help to strengthen and expand local markets. Allocations of AfT can influence the policies in developing countries, as well as, build productive capacity. Building productive capacity within a country involves providing the resources to compete in a global economy, fostering business development, and developing linkages between producers and global markets. AfT supports economic growth through encouraging countries to enact favorable trade policies. Increased productive capacity and favorable trade policies create a more efficient and effective economy both globally and domestically.

AfT provides technical assistance and support for infrastructure investments. The majority of technical assistance provided involves crops that are produced for export. However, many agricultural practices, storage practices, packaging material, and transportation methods

could be applied to crops of local importance. Many individuals that are involved in the production of export crops are also involved in the production of crops for local consumption. The establishment of channels of communication between agricultural specialists and local producers can be funded initially by AfT. However, once the channels are established technical advice remains available even after AfT funding is removed. Allocations of AfT can also be given to support infrastructure projects.

A lack of infrastructure has been recognized as a significant cause of postharvest loss. Physical infrastructure, such as roads, helps to connect local producers to markets. Development of a better road system and connecting linkages between producers and regional markets will not only reduce postharvest loss but can also increase the competitiveness of local farmers in the market. Investments in other infrastructure such as processing and postharvest stations create opportunities for farmers to process and sort produce to increase revenue at markets.

Addressing the problem of postharvest loss through the use of AfT allocations is reasonable because AfT is a recognized and established method of allocating development aid. The effective methods of monitoring and evaluating AfT would allow for monitoring of the impact of aid given on postharvest loss. AfT has also been proven to be effective in connecting and maintaining relationships between donor organizations and country specific leaders.

Since the initial establishment of the AfT Initiative in 2005 many changes have occurred. New contributors to AfT have come in the form of regional groups and private sector investments. The global environment has changed since 2005 in the mists of global financial crisis many organizations and countries are faced with major cuts in development aid. Even within developing countries radical changes are occurring, populations challenging traditional roles and requiring more transparent and accountable government activity (OECD, 2013b).

These developments are sure to change the role and presence of AfT in the near future. Proposals for the use of AfT in conjunction with other areas of development are increasing. It is practical and efficient to use already existing challenges of aid found in AfT because of the existing funding and proven success (Thow and Priyadarshi, 2013). Allocations of AfT have the potential to impact NCDs, poverty, overall quality of life. In addition to increasing trade and income, AfT allocations provide the necessary infrastructure, opportunity for policy and regulation changes, and access to a global market and global knowledge.

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CHAPTER 4

CONCLUSIONS

Developing countries need to increase food production within their own borders. Increases in population and food consumption must be matched with an increase in the available food supply. Reduction of postharvest losses of harvested fruit and vegetables will increase food availability and overall quality of life for residents.

In a food system, the period of time between when a vegetable is harvested in the field and when it is either processed or consumed is the postharvest stage. Since fresh items are living during postharvest handling any action or process applied to them impacts the quality. Any loss of an item or reduction in consumer acceptability after harvest and before consumption is referred to as postharvest loss. The specific amount of postharvest loss observed in a food system is a result of variety of factors. Characterization of the postharvest handling systems provides the opportunity to describe the systems and all factors that influence postharvest loss. Models of the postharvest handling system can be used to identify where postharvest technology will be the most appropriate and effective in reducing these losses.

Data from interviews collected using CSAM were analyzed using a grounded-theory approach to develop six models representing the postharvest handling system in Rwanda. A systems approach allowed for a generalized model of the postharvest system to be modified for recognition of economic and food safety concerns. The postharvest handling system of four crops, tomatoes, amaranth, pineapples, and bananas were evaluated to identify areas that are in need of new postharvest technologies. Preharvest practices, harvesting methods, grading, sorting,

inspection, storage locations, and transportation were identified as critical in developing strategies for reducing losses and improve the quality. Other factors shown to influence postharvest loss within the country included availability of supplies, use of culled items, access to credit, cost of production and marketing, and volatility of regional markets.

The Aid for Trade Initiative provides unique pathways of support for developing counties. AfT allocations support the economy, productive capacity, and infrastructure in developing countries to increase efficiency within the country and availability of the country to global trade markets. Capitalizing on global value chains and participating in new trade patterns provides a pathway for developing countries to enter into global trade. New AfT programs should support ways in which to connect developing countries with production networks and help establish the competiveness of developing countries. Developing skills and building infrastructure can help increase competiveness. Investments in infrastructure address a key issue in postharvest handling chains within developing countries. Working to establish appropriate and effective infrastructure and linkages not only help countries compete internationally but can also aid in reducing postharvest losses for local consumption and trade. Allocations of AfT have the potential for dramatic impact on poverty, overall quality of life. In addition to increasing trade and income, AfT allocations provide the necessary infrastructure, opportunity for policy and regulation changes, and access to a global market and global knowledge.