Tomato Postharvest Losses in Ghana: An Economic Analysis

Tomato Postharvest Losses in Ghana: An Economic Analysis

Author: Ruth Amoako-Adusei

This report is taken from an MSc thesis conducted at the Wageningen University and Research

The HortiFresh Program

HortiFresh is a program supported by the Embassy of the Kingdom of Netherlands which prioritizes commercial agriculture in its strategic plan of moving Ghana from aid to trade. It seeks to develop a competitive and sustainable vegetable sector in Ghana. HortiFresh supports vegetable producers with linkages to other value chain operators within the country and with the Dutch private sector.

Wageningen University and Research

Wageningen University and Research (WUR), located in the Netherlands, is a hub for innovative and transformative agriculture. Ranked the best agricultural university worldwide, WUR seeks to build international scholars and students who are passion driven and ready to explore the potential of nature to improve the quality of life.

Table of Contents

Executive summary 3
Acknowledgements 4
Abbreviations and Acronyms 5
1. Introduction 6
1.1 Ghana's Tomato Sector 7
1.2 Postharvest Losses 9
1.3 Postharvest Technologies 9
2. Materials and Methods 12
2.1 Study Area 12
2.2 Survey 13
2.2 Analytical methods 14
2.3 Postharvest Technology 15
3. Results and Discussion 16
3.1 Characteristics of Supply Chain Actors 16
3.1.1 Demographics 16
3.1.2 Membership of Local Associations 17
3.2 Drivers of Postharvest Losses 18
Photo 2: Sun scorched tomato 19
3.3 Postharvest Losses along the supply chain 19
3.3 Cost Benefit Analysis of Postharvest Technologies 23
4. Conclusions and Recommendations 28
References 29
Appendices 31
Appendix 1.1 Educational and training background of supply chain actors 31
Appendix 1.2 Location of Producers and retailers 31
Appendix 1.3 Factors influencing the PHL of producers 31
Appendix 1.4 Factors influencing the Interest of Producers to Use a Postharvest Technology 32

Executive summary

Postharvest losses in Sub-Sahara Africa is a major issue affecting food security especially with regards to food availability. With an estimated 374 million people in SSA experiencing severe food insecurity it is prudent to ensure that the least amount of food is lost. In this study, the case of tomato postharvest losses and postharvest technologies to reduce these losses are assessed. Tomato is an important crop in Ghana, consumed in large volumes. However, postharvest losses of tomato that occur at the pre-consumer level have been estimated at between 20-50%. To reduce these losses, postharvest technologies are suggested. The technologies focused on in this study are the use of shade and the zero energy cooling chamber. The factors influencing tomato postharvest losses as well as the interest of producers to use postharvest technologies were evaluated. A Cost Benefit Analysis was used to assess the economic effect of using the technologies suggested on the profit of the tomato producers. The results indicated that tomato producers who were members of local associations experienced significantly lower losses. Also, producers had a fairly poor perception about using a postharvest technology. The producers who perceived the cost of the postharvest technology to be greater than the benefit were less likely to use the technology. It was also found that the white cloth was a better investment option in comparison to the zero energy cooling chamber. Pre-harvest practices seemed to have a bearing on postharvest losses and as such, further research is required to better understand this relationship. Research on the PHL of tomato wholesalers and retailers is necessary in addition to this study to have a holistic overview of the tomato PHL in Ghana.

Key words: Postharvest losses, postharvest technologies, tomato, tomato supply chain, cost benefit analysis

Acknowledgements

Sincere gratitude to the Wageningen University & Research (WUR) and the HortiFresh team for putting together this piece of work. Indeed, I am grateful to my supervisor, Dr. Mariska van der Voort from the Business Economics chair group of WUR, whose guidance was instrumental in producing this work. Also, I appreciate the immense support of Dr. Irene Koomen of the Wageningen Centre for Development Innovation, who provided counsel and support especially during the data collection and analysis phase.

I appreciate the HortiFresh Ghana team with whom I shared priceless moments. Ellen, Jemima, Patricia, Ernest, Hilarion, Newman, Tony, Adwoa, Jerome and Sheila, the Program Manager of HortiFresh, among others who made me feel very much at home and provided essential technical support. I thank the independent researchers who also guided my work and helped deepen my knowledge in the field of research and the tomato supply chain. Professor Sarpong, Dean of the School of Agriculture UG, and Dr. Amissah, Head of Crop Science Department UG were very influential in the outcome of this work. Also Dr. John Addo and Dr. Adu-Kwarteng of the Crop Research Institute (CRI) Ghana gave practical insights on postharvest interventions and technologies. Dr. Appiah from the Department of Horticulture in the Kwame Nkrumah University of Science and Technology (KNUST) was also very helpful. Edwin van der Maden of WUR helped deepen my understanding of supply and value chains in agriculture.

I also thank immensely all key informants and respondents in this research. Particularly, I thank the members of the Ghana National Tomato Traders and Transporters Association for their cooperation.

All photos by the author unless mentioned otherwise.

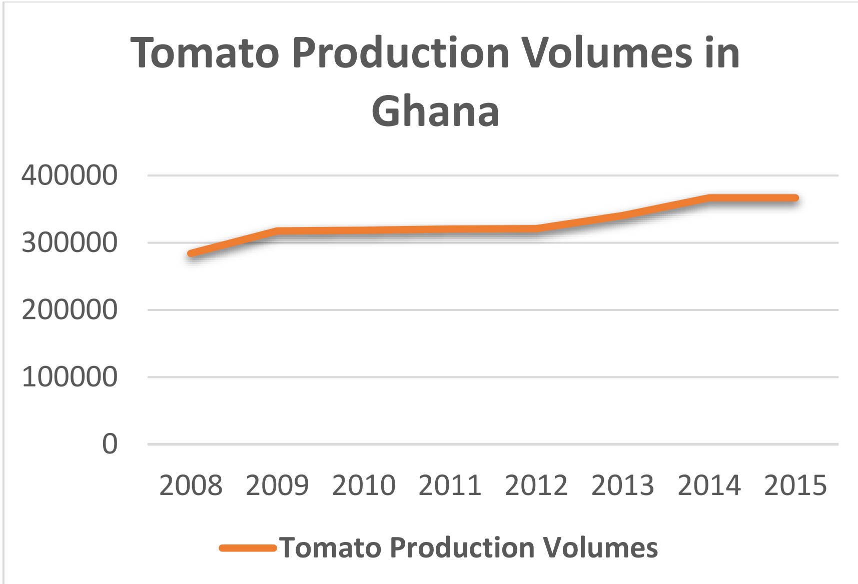
Abbreviations and Acronyms

CBA	Cost Benefit Analysis
CRI	Crop Research Institute
CSIR	Council for Scientific and Industrial Research
FAO	Food and Agriculture Organization of the United Nations
FLW	Food Loss and Waste
GHS	Ghana Cedis
GNTTTA	Ghana National Tomato Traders and Transporters Association
GoG	Government of Ghana
GSS	Ghana Statistical Service
IFPRI	International Food Policy Research Institute
KNUST	Kwame Nkrumah University of Science and Technology
MoFA	Ministry of Food and Agriculture
NPV	Net Present Value
PHL	Postharvest Losses
SSA	Sub-Sahara Africa
UG	University of Ghana
WUR	Wageningen University & Research
ZECC	Zero Energy Cooling Chamber

1. Introduction

In the Ghana Living Standards Survey (2017), tomato made up the highest proportion (11.6%) of household vegetable expenditure. Many Ghanaian dishes include a component of fresh tomatoes, and with a rapidly growing population, it is no surprise that demand for the product has increased substantially over the years (Issahaku, 2012). Council et al (2014) estimated that between 2001 and 2011, there was a more than double fold increase of fresh tomato consumption; from 175,000 tons to 370,000 tons. Tomato production is regarded as a highly profitable business and a potential area to improve the livelihood of smallholder farmers through higher income earning (Arah, 2015). Therefore, the increase in consumption rates creates a platform for smallholder farmers to increase their income by producing larger volumes of tomato to meet the demand (Arah, 2015; Melomey et al, 2019). Interestingly, tomato production volumes in Ghana have shown only slight increases over the past two decades (Fig 1.1) which is attributed to the increase in land area used for cultivation These increases as shown by the MoFA have not been large enough to meet the growing demand. Adding to that, tomato production is seasonal in nature; with majority of production taking place in the low rainfall and high rain fall seasons (Robinson & Kolavalli, 2010c). Hence, fresh tomato production volumes in Ghana are regarded as low. Due to the low production volumes in-country, the importation of fresh tomatoes from other countries such as Burkina Faso became necessary to meet the growing domestic demand (Robinson & Kolavalli, 2010a). It is of interest to know that, imported tomatoes are reported to be of a higher quality than local tomatoes, possibly due to the use of improved varieties (Van Asselt, 2018). Fresh tomato imports into Ghana are valued at 9 million U.S. dollars annually (Van Asselt et al, 2018).

Fig 1.1 Tomato production volumes in Ghana (FAOSTAT, 2016)



In response to the low production volumes, the Government of Ghana (GoG), NGO's and other private sector institutions rolled out interventions geared towards increasing the productivity of farmers. For example, the fertilizer subsidy program executed by the GoG, saw an increase in tomato production following its implementation (Fearon, Adraki, & Boateng, 2015). Research institutions have also conducted studies and implemented interventions to increase production (Melomey et al., 2019). However, these interventions may not yield the desired impact if the trend of high postharvest losses (PHL) continue. PHL referred to in this study is defined as the decrease in the quantity and quality of tomatoes between the harvest and retail stages of the supply chain (Chaboud & Daviron, 2017; FAO, 2011). Tomato PHL in Ghana is estimated to be between 20-50% (Addo et al., 2015). This implies for instance that, a 100% increase in tomato yield may result with only 50% of the quantity produced being marketable. This would mean that projected revenues mainly at the producer level may not be realized. Arah et al. (2016), confirms this, in finding that increased productivity did not translate into higher profits in many developing countries due to high levels of PHL.

This study assessed the PHL of tomato producers and wholesalers in the Ashanti and Bono East regions of Ghana where the majority of tomato production takes place (Adu-Dapaah & Oppong-Konadu, 2002). Retailers of tomatoes in major markets in the capital Accra were also included in the assessment of PHL (Robinson & Kolavalli, 2010a). Subsequently, the use of the following postharvest technologies; white cloth after harvest and the Zero Energy Cooling Chamber (ZECC), were evaluated for their economic feasibility in the context of the study area.

1.1 Ghana's Tomato Sector

Tomato is a highly valued vegetable crop in Ghana. Tomato is consumed fresh with very small volumes going into processing, though it is a highly perishable product (Robinson & Kolavalli, 2010b). Robinson and Kolavalli (2010b) notes that fresh tomatoes attract a premium price compared to trading them for processing, hence farmers prefer to sell them fresh even when prices are low on the market. Tomato puree is a popular alternative and majority of the tomato puree products consumed in Ghana are imported. Accordingly, Ghana has been described as the second largest consumer of processed tomato products in SSA (Baba, Yirzagla, & Mawunya, 2013). Given that tomato is described as a key ingredient in the Ghanaian cuisine, it follows that there ought to be a very efficient supply chain to meet the demand of consumers (Van Asselt, 2018). Fig 1.2 shows the supply chain of tomato in Ghana consisting of four main stages; Input supply, production, transportation and distribution and retail as suggested by Kumi (2017). Power is concentrated around the wholesalers, where their strong association, Ghana National Tomato Traders and Transporters Association (GNTTTA) enables them to have control over production practices, wholesale prices, as well as the volumes of tomato available on the retail market (Robinson & Kolavalli, 2010a). The wholesalers for instance are known to sponsor producers with loans or inputs such as seeds and fertilizers, hence influencing their production practices and the prices of tomatoes. The producers and retailers however are price takers with very little bargaining power (Robinson & Kolavalli, 2010a).

Figure 1.2 Tomato Supply Chain in Ghana (Kumi, 2017)

Tomato producers have been unable to meet the demand of tomatoes in Ghana over the past years. MoFA (2015) estimates that producers are producing at 50% capacity; potential yield is estimated at 20 tons/hectare whiles actual yield averages at 10 tons/hectare. The apparent yield gap is suggested to be a result of various factors. Varietal choice (Robinson & Kolavalli, 2010c), improper plant protection, limited use of irrigation and non-adoption of staking and pruning (Gonzalez et al., 2014; Van Asselt, 2018) are suggested as factors contributing to low yields. Another pressing issue leading to the inability of producers to meet local demand is the seasonal nature of production in the country. Tomato is in high demand all year round however there are periods within the year, usually between January and May, where there is almost no local tomato production (Van Asselt, 2018). Hence to offset the demand during these periods, fresh tomatoes are imported from neighbouring countries with the major supplying country being Burkina Faso. This has over the years caused severe price fluctuations; high prices when low volumes of tomato are produced in-country and low prices during periods of high volumes of production. Robinson and Kolavalli (2010a) found that price fluctuations are also influenced by the wholesalers. The wholesalers regulate the inflow of tomatoes into the markets and hence can create artificial shortages, here also gaining control over price.

1.2 Postharvest Losses

PHL remains a relevant topic in SSA, especially in times where an estimated 374 million people in SSA experience severe food insecurity (FAO et al, 2018). In SSA, an estimated 40% of all food crops are lost between the harvest and pre-consumer levels, leaving only 60% of the food crop available on the market for the consumers to purchase (FAO, 2011). With such high levels of losses, there are sporadic food shortages and severe price fluctuations of food commodities, leaving the poor and vulnerable in the society food insecure. In horticultural crops such as vegetables and fruits, PHL are even much higher because of their perishable nature. PHL of vegetables in SSA is estimated to range between 30-50% (Baral & Hoffmann, 2018; Kitinoja, Saran, Roy, & Kader, 2011). Relevant to this study, tomato PHL in Ghana have been estimated at between 20-50% (Aidoo, Danfoku, & Mensah, 2014; Gonzalez et al., 2014) and this is attributed to a number of causes. Poor postharvest handling has been identified as one of the main causes (Aidoo et al., 2014). It occurs in various forms, from bruises during harvesting, rough packaging material such as wooden boxes, dense packing of tomatoes into single large wooden boxes and the poor road network. Also, during periods of glut, losses reach unprecedented levels as the lack of storage facilities and the short shelf life of the produce leave the producers with very few options other than to sell to wholesalers directly after harvest (Van Asselt, 2018). Farmers, in the period of glut are reported to leave their produce to rot in the fields due to lack of ready market. Given that farmers and traders lack the knowledge and skill in maintaining quality and hence prolonging the shelf life tomatoes the trend of PHL may persist (Yeaboah, 2011). This severely curtails efforts to increase production, which is meant to translate into higher food availability as well as stable tomato prices (Robinson & Kolavalli, 2010a). Estimates of current losses especially specific to the study area will help paint a picture of the extent to which impact can be made.

1.3 Postharvest Technologies

Postharvest technologies are primarily aimed at reducing both quality and quantity losses of fresh produce. In this study, postharvest technology is defined as the science and techniques applied to agricultural commodities after harvest for the purposes of preservation and quality control to meet the foods and nutritional requirements of consumers in relation to their needs (Sonam, 2016). Postharvest technologies range from very simple low cost technologies to capital intensive machinery. Saran et al. (2010) conducted a study to find postharvest technologies suitable for smallholder farmers. Five postharvest technologies were proposed; Plastic containers for transporting, use of shade, improved field packing systems, low energy cool storage (Zero energy cooling chamber) and the CoolBot equipped small cold rooms. Of these technologies, two were relevant to the actors used in this study, the use of shade and the low energy cool storage. They were selected because of the use of tomatoes in conducting trials, the study being located in Ghana and the provision of evidence on the efficacy of the technology. The postharvest technologies are using white cloth cloth (Adu-Kwarteng, 2017; Saran, Roy, & Kitinoja, 2010) to shade harvested produce before marketing and the Zero Energy Cooling Chamber (ZECC) (Baral & Hoffmann, 2018; Kitinoja, 2013) to preserve the quality of tomato.

Fig 1.3 Postharvest technologies selected for the study

Use of Shade cloth

Photo: Adu-Kwarteng (2017)

Zero Energy Cooling Chamber

Photo: Decker (2019)

1.4 Objectives of the study

In this study the effect of using postharvest technologies on the profit of tomato producers was assessed. This was done by first estimating the PHL that occurs at the producer level and also further down the supply chain. Following this, the interest of the tomato producers to use postharvest technologies was assessed. Then, a Cost Benefit Analysis (CBA) was conducted to evaluate the selected postharvest technologies for their effect on profits made.

Fig 1.4 Impression of handling of tomatoes in the various steps of the supply chain

Sorting at harvesting

Filling crates with tomatoes at harvest

Crates being loaded into truck

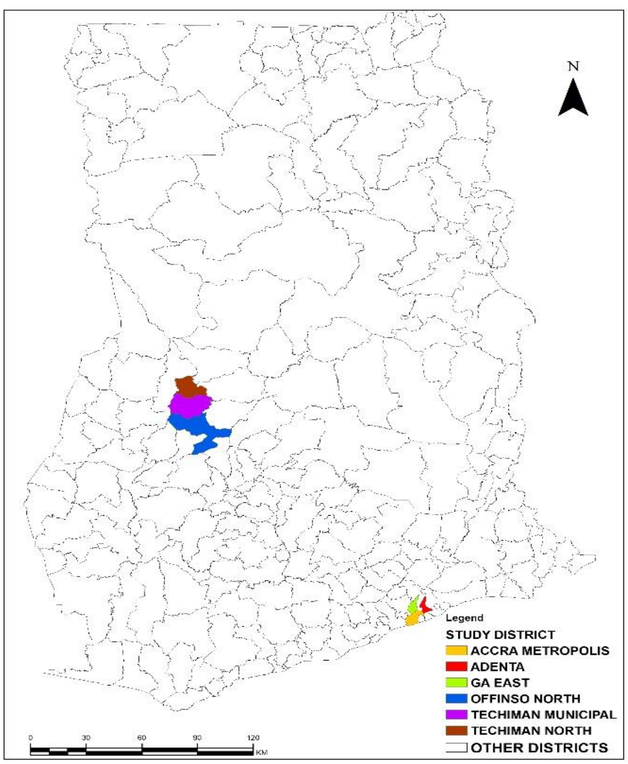
Retailer sorting and grading tomatoes at the market

2. Materials and Methods

2.1 Study Area

Three towns were selected based on the tomato producing focus areas under the HortiFresh project. The study area for surveying the producers and wholesalers comprised of the following towns; Akumadan and Afrancho in the Offinso North District as well as Tuobodom in the Techiman North District. Collectively, 80% of the inhabitants of these towns above the age of 18 years are into tomato farming. In Akumadan for instance, tomatoes constitute 90% of all cultivated crops in the area (Ntow et al. (2008). These areas also record the highest yield per unit area of tomato in Ghana (Robinson & Kolavalli, 2010c). The sampling of retailers was conducted in the Agbogbloshie market as well as two other major markets, Makola and Madina markets (Adenta Municipality and Accra Metropolis). According to Robinson and Kolavalli (2010a), the Agbogbloshie and Makola markets are the largest tomato wholesale markets and are located in the cities which have the highest tomato consumption rates due to the dense population. These markets are located in the capital city of Ghana, Accra, an average of 365 kilometres from the production areas sampled. Figure 2.1 shows the districts in which the study was conducted.

Figure 2.1 Map of Ghana showing study area



2.2 Survey

To obtain data on the quantities of PHL and the factors influencing both the PHL and the use of postharvest technologies, a structured questionnaire to be administered to the supply chain actors, was developed. The actors being the producers, wholesalers and retailers of fresh tomatoes in the study area. Questionnaires were developed specific to each selected actor. Each questionnaire was divided into four main sections; socioeconomic characteristics, supply chain actor's activities, proportion of PHL and postharvest technologies, with an extra section for production costs in the producer questionnaire. The questionnaires consisted mainly of close ended questions for the purposes of quantitative analysis. The questionnaire was administered verbally by enumerators and responses were recorded using the Insyt data collection application with electronic tablets. A pre-test of the questionnaires was done prior to its administration. Four tomato producers were purposively selected in Akumadan and Tuobodom and two retailers were randomly selected from the Makola market for this pre-test. The results of the pre-test were discussed with Agronomists from HortiFresh and a postharvest expert from CSIR who provided relevant feedback for the revision of the questionnaires. The sample size of producers was determined based on a pre-census of tomato producers conducted by HortiFresh in the selected areas.

Figure 2.2: Questionnaire administration to producer

The purposive sampling method was used in selecting wholesalers and retailers to answer the questionnaires. Wholesalers and retailers were selected as respondents if they indicated that they traded only fresh tomatoes. For the purposes and scope of this study, a sample size of $n \geq 30$ for either wholesalers and retailers was chosen in order to obtain data of a sufficient nature for the analysis. This is also consistent with the Central Limit Theorem which assumes that random samples of size equal to or larger than 30 have sample mean which approaches a normal distribution and is representative of the population (Islam, 2018).

The questionnaires were administered between mid-November to mid-December which coincided with the harvest season of the producing areas sampled. During that time period also, the retailers were being supplied with tomatoes from the producing areas covered in this study. The producers were asked to provide answers based on the previous cropping season. A total of 127, 26 and 39 responses were obtained from producers, wholesalers and retailers respectively. Responses which had for example questions on PHL not answered were considered as incomplete and hence excluded from the statistical analysis. This resulted in an effective sample size of 112 producers, 25 wholesalers and 39 retailer responses.

2.2 Analytical methods

The PHL estimation protocol proposed by IFPRI (2018) was used to estimate the PHL of the actors. The PHL protocol is centred on supply chain activities and actors in order to properly capture losses that occur pre-consumer. Two methods from the PHL estimation protocol are used; self-reported method and price method.

Self-reported method: In the self-reported method, respondents were asked to estimate their PHL within the reference period stated. Distinctive to this study, PHL estimates were categorized into low rainfall and high rainfall seasons. This was done to capture the differences in PHL occurring in the two main tomato cropping seasons in the country. Responses on estimated PHL was added up and PHL estimates made using simple averages. PHL was estimated for the low rainfall season and high rainfall season in kilograms per acre. The PHL was also presented as a percentage of the average yield of the area. This was used for the producers and retailers since their losses could be estimated quantitatively.

Price method: The price method uses the market price of the tomatoes as a proxy for measuring quality deterioration. It compares the ideal sale value of a quantity of product to the actual value obtained from that product, the difference being the quality loss. This is particularly useful in this study because wholesalers have limited direct contact with fresh tomatoes and hence experience mainly quality loss. Therefore, PHL at wholesaler level was quantified as;

$$\boldsymbol{ValueLoss}_{\mathbf{p}} = \boldsymbol{V}_{\mathbf{Ideal}} - \boldsymbol{V}_{\mathbf{PH}}$$

V_{ideal} is calculated by multiplying the wholesaler's product quantity by the average ideal sales price for the product. V_{PH} is the total value the wholesaler obtained for the product as personally assessed by himself. This assessment is used as a proxy measure for the economic value of the tomato loss.

To assess the factors that influence PHL of producers in the high and low rainfall seasons as well as the factors that influence the interest of producers to use a postharvest technology, regression analysis was used. The PHL data, being continuous in nature informed the selection of the ordinary least squares regression for its analysis. Data on the interest of producers was recorded in a binary form; Yes or No. Hence, a logit model was appropriate for the analysis (Shee et al., 2019). The statistical software STATA 15 was used to analyse the data.

2.3 Postharvest Technology

The two postharvest technologies (white cloth and ZECC) were selected since they had a proven record of reducing PHL and also were cost efficient in comparison to other more complex technologies. The technologies were intended to be used by the producers since they begin the supply chain and hence the chain of PHL as well. Following the selection of the postharvest technologies, the cash flow of an average production year, was accounted for. Irrigation costs were included only for the low rainfall season as sufficient water availability is assumed for the high rainfall season. Revenue from the sale of fresh tomatoes based on yield estimates from this study less estimated PHL was used to represent benefits for an average production year. The price of fresh tomatoes per kg was calculated from the field survey to cater for price peaks and falls throughout the year.

3. Results and Discussion

3.1 Characteristics of Supply Chain Actors

3.1.1 Demographics

The socioeconomic characteristics of the supply chain actors interviewed indicate that 71% of the producers sampled were male (Table 3.1). Studies on gender inequality at producer level have found that low response rates from females in similar studies may be due to the situation where most of the females make up the labour force for farming but do not own farms themselves (Ogunlela & Mukhtar, 2009). Also, females have less access to male labour and other inputs due to lower financial status and lower respect for females, characteristic of patriarchal societies (UN Women, 2019). On the other hand, at the wholesaler and retailer level, the majority of the respondents were female. This is in line with findings of Robinson and Kolavalli (2010a) where the wholesale and retail section of the tomato supply chain is female dominated. Also in line with the findings of Robinson and Kolavalli, it was observed on the field that the dominant nature of the wholesalers allowed them to control significant portions of the supply chain. The wholesalers determined price and the flow of fresh tomatoes into the various markets country wide. With regards to age, the majority of respondents along the supply chain were above the age of 35 years. This is also observed in similar studies conducted in SSA (Aboderin, 2012). The majority of all supply chain actors interviewed indicated some level of formal education (see table 1 in the appendix), the majority had up to Junior High School level education (approximately at 15 years of age). With producers for instance, it was observed that after Junior High School, it was more attractive to go into tomato production. Informal conversations with young producers showed that the monetary gains was an incentive for the young people in the study area to drop out of school and enter into tomato production.

Table 3.1 Descriptive statistics of supply chain actors

Variable	**Producers N= 113**	**Wholesalers N= 25**	**Retailers N= 39**
Age < 35 years	29.2%	21.7%	33.3%
Age > 35 years	70.8%	78.3%	66.7%
Male	84%	4%	8%
Female	16%	96%	92%
No Formal education	17%	12%	15%
Formal education	83%	88%	85%

**The age of adulthood considered above 35 years in Ghana (Efem, 2007)*

Table 3.2 shows that 85% of the producers were observed to use recycled seeds which is termed as the local variety. Power Rano, Konkon and Pectofake were among the popular local varieties used by the producers. 3% of the producers indicated that they used only improved varieties such as Pectomech and 12% indicated that they used both the improved and local varieties. The predominant reason given for the choice of the local variety was the market preference for the produce (30%). Other reasons mentioned in descending order of preference were availability of the seeds (28%), ease of cultivation (27%), and ability to withstand postharvest damage (10%). From the area cultivated, producers obtained average tomato yields of 5.7 tons/acre (14.3 tons/ha).

Table 3.2 Production Characteristics

Variable	Value
Tomato Farm Size (acres)	2.2
Experience in tomato farming (years)	17.5
Yield (tons/acre)	5.7
Varieties	
Local (Recycled seeds)	85%
Hybrid/Improved Varieties	3%
Both	12%

3.1.2 Membership of Local Associations

The membership of respondents in local tomato organizations varied along the supply chain. Only 19% of producers belonged to a local tomato producer's association. The wholesalers on the other hand recorded 68% of respondents belonging to a tomato wholesalers' association. The predominant association was the GNTTTA. The GNTTTA is a well-structured association regulating the tomato supply chain in Ghana. This likely led to the inability of the wholesalers to determine quantities of PHL because their system allows for the regulated movement of tomatoes hence leaving little room for excesses that would result in tomatoes being lost. The name Ghana National Tomato Traders and Transporters Association, GNTTTA, suggests that retailers are to be members of this association as well. However, this was not found to be the case as only 15% of the retailers sampled were members of an association, mostly the GNTTTA. This results contrasts with the findings from Robinson and Kolavalli (2010a). The sampling procedure used for retailers may have contributed to this finding. However, it was observed that, for each market that was sampled, an authority figure known as the 'tomato market queen' was present to control the supply of tomato into the market and also negotiate process with wholesalers. The tomato market queen represented the individual retailers in the larger GNTTTA. Hence, indirectly the retailers belonged to this association, however, they did not consider themselves active members, especially in terms of decision making.

3.2 Drivers of Postharvest Losses

Along the supply chain, the actors described the factors that drove their PHL. Poor weather conditions on farm, was the most prevalent driver of PHL given by producers. The poor weather condition described here includes excessive rainfall and sun scorching of the tomatoes (Photo 2). For wholesalers, the main driver of PHL was the poor quality of tomatoes received from producers. The wholesalers mentioned that varieties used by producers yielded poor quality tomato fruits. Retailers mentioned the overuse of agrochemicals by the producers as the main driver of PHL.

Pesticide use: The use of pesticides is a widely used practice in tomato farming. Farmers mention that various pests attack their crops during the production period. Also blight, a fungal disease of tomato, causes severe damage to their production. Blight attacks are more pronounced due to high temperatures and humidity. As such fungicides are used heavily. The pictures below were taken from a local tomato farm in the Techiman North district where used bags of pesticides were found scattered under trees (where most likely the mixing of the chemical took place). The farm owner noted that he used pesticides above the recommended dose and also did not observe the pre- harvest interval.

It is evident that, the main drivers of PHL for producers, retailers and wholesalers were related to pre-harvest activities that took place on the farm (Table 3.3). Sibomana, Workneh, and Audain (2016), confirm this, finding that the postharvest quality of tomato fruits are significantly affected by pre-harvest practices and conditions such as agrochemical application as well as light and rainfall intensity during the growing period. This finding provides a stepping stone for research to be conducted into improving pre-harvest practices that would have an effect on postharvest quality.

Table 3.3 Causes of PHL of Supply Chain Actors

Producers	%	Wholesalers	%	Retailers	%
Poor weather condition	37%	Poor quality of tomatoes from producers	40%	Overuse of agrochemicals by producers	33%
Lack of ready market	31%	Breakdown of transporting vehicle	28%	Poor weather conditions on farm	23%
Pest infestation	24%	Poor weather conditions on farm	15%	Poor transportation of produce	15%
Unsuitable Packaging material	4%	Pests infestations carried from the farm	6%	Pest infestations carried from the farm	10%

**The causes shown are those mentioned by the respondents as most important*

Photo 2: Sun scorched tomato

3.3 Postharvest Losses along the supply chain

PHL of producers and retailers in the high rainfall season (April to November) were much higher than in the low rainfall season (December to March; Table 3.4). The low rainfall season also coincides with the lowest in-country tomato production as well as peak imports of fresh tomatoes from neighbouring countries (Van Asselt et al, 2018). Intense rainfall greatly compromises the quality of tomato fruits causing them to be watery and hence deteriorate more quickly. The wholesalers reported their losses in terms of a reduction in price, carried out in a very subjective manner. Therefore, for tomatoes of a visibly reduced quality, an average of 54% reduction in price is to be expected.

Table 3.4 PHL of supply chain actors

Postharvest Losses	Mean	St. Dev	Min	Max	% PHL
Producers (kg/acre)					
PHL in low rainfall season	278	193	0	780	4.9
PHL in high rainfall season	493	356	0	1398	8.7
Wholesalers					54
Retailers (kg/180kg box)					
PHL in low rainfall season	15	16	0	60	8
PHL in high rainfall season	50	29	20	120	28

Factors influencing PHL of producers are membership of producers in a local organization, experience, farm size and variety used all had a significant effect on PHL (Table 3.5).

Membership of Local Association: Producers were likely to incur less PHL when belonging to a local farmer association seemingly due to benefitting from the expertise of fellow members. Aidoo et al. (2014) with a similar finding stated that producers in such organizations were more able to connect with wholesalers leading to pre-planned harvesting and as such reduced PHL.

Experience in Farming: Older producers were likely to incur higher PHL since they are assumed to be less willing to adopt new and efficient production practices.
Variety: Using the local variety likely results in higher PHL presumably because of its poor postharvest quality described in detail by Melomey et al. (2019).

Table 3.5 Factors influencing the PHL of producers

PHL in kg/acre	PHL in Low rainfall season	PHL in High rainfall season
Producer characteristics		
Membership of Local Association	-120.1**	-281.3**
Experience in farming	68.4 *	52.8
Production characteristics		
Farm size	-77.6*	-49.9
Variety (local)	37.2	299.3**

**** p<0.01, ** p<0.05, * p<0.1, figures represent coefficient of the various variables*

Farm Size: On average, the larger the farm size the lower the PHL estimated. This is contrary to the findings of Addo et al. (2015) who suggested that producers with large farm sizes grapple with inadequate storage facilities and difficulties in transporting the large quantities of produce leading to higher PHL. However, the link with farm size is not concretely established in this study or that of Addo et al. (2015).

Storage: Following up with issues of storage it was found that 95% of the respondents did not store their tomatoes after harvest, suggesting that storing produce after harvest is not common practice in the area. This disproves the possibility of inadequate storage leading to higher PHL. The mode of transportation however, could possibly contribute to the increase in PHL. Tomatoes are tightly packed on wooden boxes, where high compression within the box combined with the poor road network could increase PHL.

Post Management Training: Based on a study by Beune (2018) and Shee et al. (2019), it was hypothesized in this study that producers trained in postharvest management would have lower PHL. However, this hypothesis could not be proven since the relationship between these two variables was found to be statistically insignificant (Appendix 1.3). Rather, in this study, a negative correlation between PHL and training in postharvest management was found in the low rainfall season suggesting lower losses whereas a positive correlation was found in the high rainfall season. The positive correlation is contrary to the findings of Shee et al. (2019). A suggested explanation is that, in the low rainfall season, having postharvest training may lead to lower losses as observed due to the knowledge and technical skills acquired and practiced. However, in the high rainfall season, PHL are most likely caused by poor weather conditions which cannot be mitigated with training but rather an adaptation of production practices to reduce the effects of the poor weather.

Table 3.6 Factors influencing the Interest of Producers to Use a Postharvest Technology

	Interest in using PHM (1=Yes, 0=No)	**Marginal Effect**
Producer characteristics		
Location	2.2**	0.39
Production characteristics		
Variety (local)	-1.5*	-0.22
Postharvest Management Training	3.1***	0.37
Storage	3.1***	0.20
Producer perceptions		
Focus on Cost	-2.7***	-0.47
Support Program to aid adoption	4.3*	0.78
Adoption of prev. tech	-1.4**	-0.25
_cons	-4.2	
Pseudo R^2	0.3645	

**** p<0.01, ** p<0.05, * p<0.1, standard deviations in brackets*

Table 3.6 shows the factors that significantly influence the interest of producers in using a postharvest technology.

Postharvest Management Training: Consistent with Beune (2018), it was noted that the adoption and use of postharvest technologies was more successful if preceded by awareness creation and trainings.

Focus on Cost: Producers who perceived to benefit from the technologies were more inclined to use it than those who did not perceive to benefit from the technology. This follows from the principle of maximizing utility where consumers attempt to gain the greatest value possible from their investments.

Support Program to Aid Adoption: Putting support programs to aid producers in using the technology through financial and technical assistance makes producers more inclined to use postharvest technologies. This is in line with the innovation decision process by Rogers (2010) where he suggests that adopting technologies requires technical assistance to the adopters.

Adoption of previous technology: Interestingly, producers who had previously adopted other technologies, not necessarily related to reducing PHL, were less inclined to use postharvest technologies. Producers in this category noted that they had been duped or invested in technologies that did not perform as expected. Hence, it created a sense of weariness and fear to invest further in technologies. Suggestions given by the producers indicated the need to provide trials which demonstrate the efficacy of the technology to persuade them to use the technology.

3.3 Cost Benefit Analysis of Postharvest Technologies

After determining what influences interest in PHL, it was prudent to assess the feasibility of selected technologies deemed suitable for the tomato producers in the study area. The Cost Benefit Analysis (CBA) begins with the cash flow for an average tomato production year, this is shown in table 3.7 for both the low rainfall season and the high rainfall season. All monetary values were converted from Ghana Cedis (GHS) to Euros using a conversion factor of 0.17. The variable costs consist of inputs such as labour, pesticides, fertilizer and seeds. The cost of irrigation is included only in the low rainfall season due to the assumption of sufficient water availability in the high rainfall season. Labour contributed the highest variable cost of 5,682.40 GHS (equivalent to €966) per acre while seeds cost the least with 200 GHS (€34) a year. The fixed costs include land use, knapsack sprayer and basic but essential farm implements such as hoe and cutlass. At the end of an average production year a profit of 5,270.60 GHS (€896 euros) is expected.

Table 3.7 Cash flow of Average Production Year (Euro)

Average Tomato Production Year		
	Low Rainfall Season	**High Rainfall Season**
i) Revenues		
Yield (kg/acre)	5700	5700
PHL of tomato (kg/acre)	279	496
Revenue (€0.28/kg)	1518	1457
ii) Variable costs		
Labor	483	483
Fertilizer	204	204
Agrochemicals	260	260
Irrigation	34	0
Seeds	17	17
Total	998	964
iii) Fixed Costs		
Depreciation	8	8
Land use	26	26
Knapsack sprayer	21	21
Farm implements	3	3
Total	58	58
Total Profit	**897**	

The cash flows for the white shade cloth and the ZECC investments are shown in tables 3.8 and 3.8 respectively. Prices quoted for the use of the shade cloth were based on prevailing market prices. Investing in the shade cloth costs €646 for the 3 years and should be discarded and news ones purchased afterwards. The PHL used was reduced by 10% in accordance with the findings of Adu-Kwarteng (2017). All other costs remained the same as that of an average production year. In the first year a loss of €51 is made. In the second and third years a discounted profit of €517 and €450 are made respectively. Finally, at the end of the third year a positive Net Present Value (NPV) of €916 is realized.

Table 3.8 Cash flows of using white shade cloth (Euro)

Item	**Year 1**	**Year 2**	**Year 3**
i) Postharvest Technology Investment			
Shade Cloth (€/acre)	646	0	0
Total	646	0	0
ii) Revenues	0	0	0
Yield (kg/acre)	11400	11400	11400
PHL using white shade cloth (kg/acre)	698	698	698
Revenue (€0.28/kg)	2997	2997	2997
iii) Variable costs			
Labour	966	966	966
Fertilizer	408	408	408
Agrochemicals	520	520	520
Irrigation	34	34	34
Seeds	34	34	34
Total	1962	1962	1962
iv) Fixed Costs			
Depreciation	339	339	339
Land use	51	51	51
Knapsack sprayer	43	43	43
Farm implements	7	7	7
Total	440	440	440
Profit	-51	595	595
Net Present Value of Profit	-51	517	450
Total Net Present Value			**916**

The cost of constructing an 800kg capacity ZECC (Baral & Hoffmann, 2018) was estimated at €1,913 (table 3.9). The cost to cover water used for sprinkling the ZECC to enable it maintain its cooling process was set at €204 a year. The PHL was reduced by 62.5% in accordance with the findings of Kitinoja (2013). Extra labour costs were factored in due to an increased frequency of harvesting from once a week to twice a week to keep an optimum load of the ZECC at any given time. Other costs remained the same as that of an average production year. In the first year a loss of €1,629 is made. In the second and third years a profit of €290 and €252 are made respectively. However, this could not offset the loss made in the first year. Hence a negative NPV of €1,087 was realized at the end of the third year.

Table 3.9 Cash flows of using ZECC (Euro)

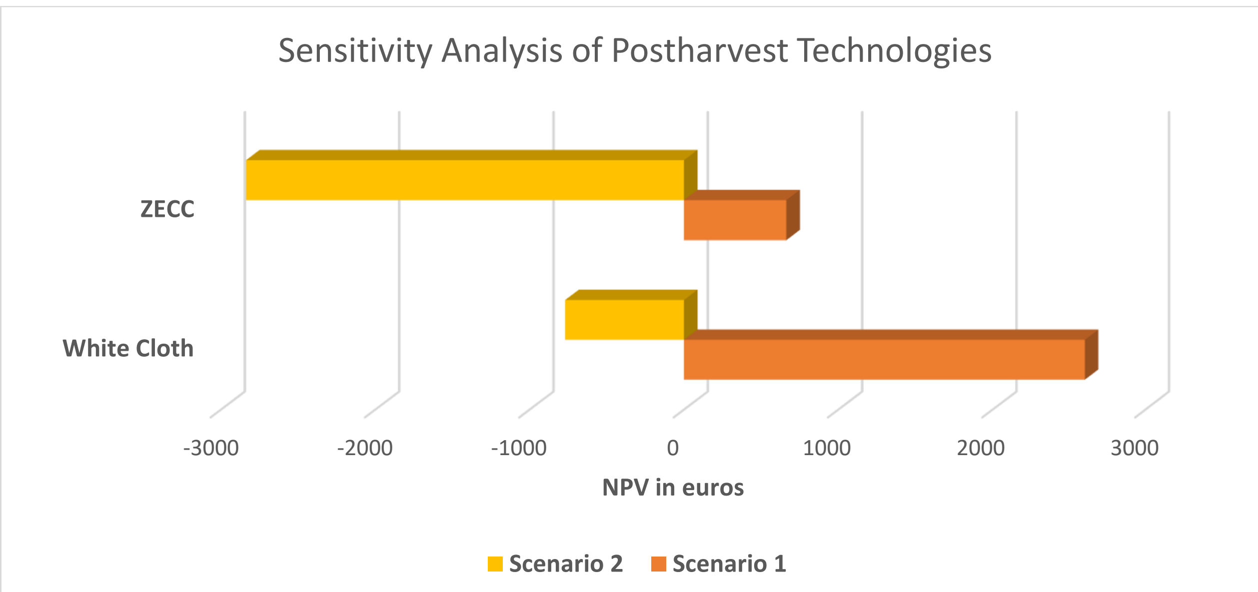
Item	Year 1	Year 2	Year 3	
i) Postharvest Technology Investment				
ZECC (800kg)	1913	0	0	
Water (800kg capacity ZECC)	204	204	204	
Total	2117	204	204	
ii) Revenues				
Yield (kg/acre)	11400	11400	11400	
PHL using ZECC (kg/acre)	291	291	291	
Revenue (€0.28/kg)	3111	3111	3111	
iii) Variable costs				
Labour	1170	1170	1170	
Fertilizer	408	408	408	
Agrochemicals	520	520	520	
Irrigation	34	34	34	
Seeds	34	34	34	
Total	2166	2166	2166	
iv) Fixed Costs				
Depreciation	356	356	356	
Land use	51	51	51	
Knapsack sprayer	43	0	0	
Farm implements	7	0	0	
Total	457	407	407	
Profit	-1629	333	333	
NPV of Profit	-1629	290	252	
Total NPV				**-1087**

Comparing the two technologies in terms of NPV, the use of the white shade cloth as shade is a better investment option than the use of the ZECC. Although the ZECC reduces PHL by a higher proportion, its high initial cost is difficult to cover within its life span considering average production years. According to Saran et al. (2010), it takes 6 years after investing in the ZECC to break even, after which profits are realized. This could not be assumed in the current study due to the assumption of its deterioration after 3 years and the need to replace it entirely. Using the white shade cloth results in a loss in the first year, however in the next year the producer breaks even and earns profit enough to cover up the cost of investing in the white shade cloth.

Table 3.10 Sensitivity Analysis description

Scenario	Description
Scenario 1	20% increase in farm gate price
Scenario 2	20% decrease in farm gate price

Figure 3.1 Sensitivity Analysis of White shade cloth and Zero Energy Cooling Chamber



When the two technologies were subjected to a sensitivity analysis as described in table 3.10, it was observed that fluctuations in price can have serious effects on the feasibility of the technologies. Figure 3.1 shows the results of the sensitivity analysis. For the ZECC, the increase in farm gate price resulted in a positive NPV of €663, however with the decrease in price, the NPV was furthered reduced to a negative NPV of €2,837. Increasing the farm gate price increased the NPV of using the white shade cloth to €2,603 whiles a reduction in the farm gate price resulted in a negative NPV of €770. The change in price for the white shade cloth investment led to a 184% change in the NPV. Similarly, for the ZECC investment the change in price led to a 161% change in NPV.

With an increase in price both technologies are feasible and provide positive NPV's. However, with a decrease in price the white shade cloth is no longer feasible to use and a producer would be better off not attempting to reduce PHL. In addition, the white shade cloth showed a higher sensitivity to the price changes than the ZECC possibly due to the lower initial cost of the white shade cloth investment. The price sensitivity of both technologies can have a serious impact on the perceptions of farmers about the technologies. This relates especially to producers who already perceive incurring higher costs than benefits when investing in a postharvest technology. Results such as this could be a huge disincentive especially in the case where the uncertainties cannot be predicted and price is highly volatile. Also, producers being price takers makes them even more vulnerable to this situation. In choosing a postharvest technology to recommend, it seems logical to select the white shade cloth over the ZECC. However, in a study by Kitinoja (2013), the selection of a postharvest technology was based on a 30% increase in revenue realized when the postharvest technology was used. This can be replicated in this study, however conclusions drawn may be misleading. This is because, price fluctuations in the tomato supply chain are very pronounced and can have a major effect on revenues obtained when using the postharvest technology.

4. Conclusions and Recommendations

This study concludes that the use of the white shade cloth as shade for harvested produce is feasible as compared to the use of the ZECC technology. Although this is better suited to the producers since majority do not store their produce, caution must be taken in recommending it to producers, especially those who are risk averse. This is mainly because a sensitivity analysis of both technologies showed how sensitive both technologies are to price fluctuations. This connotes that external economic shocks as well as internal price controlling by wholesalers can render the technology not feasible or very profitable to use. To mitigate this, producers should be encouraged to form strong farmer associations, after the following factors influencing PHL have been considered. Having strong and unified association structures will enable producers to influence and negotiate farm gate prices. In this way, using the ZECC may even become an option when producers can negotiate price while controlling the flow of tomato supply by storing their produce. Also, it would be prudent for the public sector, NGO's and other organizations to invest in training producers on improved postharvest management as this positively influences their interest in using postharvest technologies. Similarly, when introducing the postharvest technologies, support programs must be implemented to the producers to guide them on its use and also provide technical support when needed.

With regards to PHL, it was found that pre-harvest practices may have an appreciable effect on the postharvest quality of tomatoes and hence subsequent PHL. Particularly, attention must be paid to the variety used by producers as the use of the local variety led to increased PHL. Demonstration plots and trials involving producers should be carried out to enable the producers witness the advantages of the improved varieties. Further the seeds of these improved varieties must be accessible to producers. In depth research involving economic analysis should be carried out to better understand the effects of pre-harvest practices on PHL. Also, training on postharvest management must be frequently carried out to ensure producers reduce losses that are attributed to rough handling. In line with this, the design of the wooden boxes used in the tomato trade should be reconsidered and alternative options such as re-usable plastic crates be evaluated. In Nigeria, the use of the re-usable plastic crate has seen a high rate of adoption and studies are being conducted to establish its relation with reducing PHL. Last but not least, stakeholder engagements involving all supply chain actors must be held regularly to identify lapses in the chain which increase PHL and ultimately work together to improve the efficiency of the tomato supply chain.

The following recommendations are suggested:

1. The formation of structured farmer associations should be encouraged among farmers
2. Using improved tomato varieties and ensuring that seed is accessible to the farmers
3. Training producers on improved postharvest management methods
4. Program for introducing and aiding the adoption of postharvest technologies in the selected communities.

References

Aboderin, I. (2012). Ageing Africa: opportunities for development. *Global population ageing: Peril or promise, 161*(242), 69-73.

Addo, J., Osei, M., Mochiah, M., Bonsu, K., Choi, H., & Kim, J. (2015). Assessment of farmer level postharvest losses along the tomato value chain in three agro-ecological zones of Ghana. *International Journal, 2*(9), 2311-2476.

Adu-Dapaah, H., & Oppong-Konadu, E. (2002). Tomato production in four major tomato-growing districts in Ghana: Farming practices and production constraints. *Ghana journal of agricultural science, 35*(1), 11-22.

Adu-Kwarteng, E., Bortey, H. M., Aidoo Snr., A., Adu-Appiah, A. and Amoa-Owusu, A. (2017). *Temperature management strategies for tomato postharvest handling in a developing economy: the case of Ghana*. Paper presented at the 4th ISHS Asia Symposium on Quality Management in Postharvest Systems, Jeonju, Republic of Korea.

Aidoo, R., Danfoku, R. A., & Mensah, J. O. (2014). Determinants of postharvest losses in tomato production in the Offinso North district of Ghana. *Journal of Development and Agricultural Economics, 6*(8), 338-344.

Baba, I., Yirzagla, J., & Mawunya, M. (2013). The Tomato Industry in Ghana–Fundamental Challenges, Surmounting Strategies and Perspectives. A Review. *International Journal of Current Research, 5*(12), 4102-4107.

Baral, S., & Hoffmann, V. (2018). *Tackling post harvest loss in Ghana: Cost-effectiveness of technologies*: Intl Food Policy Res Inst.

Beune, R. (2018). *Income intervention quick scan: post-harvest loss prevention measures: Farmer Income Lab Intervention Quick Scan*. Retrieved from

Chaboud, G., & Daviron, B. (2017). Food losses and waste: navigating the inconsistencies. *Global Food Security, 12*, 1-7.

Council, N.-A. B., Rijk, M., & Beatrixlaan, P. (2014). Factsheet–Vegetables Ghana. *Netherlands. Retrieved, 5*(31), 2015.

Decker, K. d. (2019). Retrieved from https://www.notechmagazine.com/category/diy

Efem, N. (2007). *African Youth Charter: Prospects for the Development of the African Youth.* Paper presented at the Workshop on the Appropriation, Dissemination and Implementation of Regional Instruments and Endogenous Democratic Governance and Conflict Prevention Mechanisms in West Africa, Dakar and Saly, Senegal. Retrieved from http://www. oecd. org/swac/events/42259218. pdf [Accessed 16 April 2016].

FAO. (2011). Global Food Losses and Food Waste - Extent, causes and prevention. *Rome: Food and Agriculture Organization of the United Nations*.

FAO, I., UNICEF, WFP and WHO. (2018). *The State of Food Security and Nutrition in the World 2018. Building climate resilience for food security and nutrition*. Rome: FAO.

FAOSTAT. (2016). FAO statistical database, Rome.

Fearon, J., Adraki, K. P., & Boateng, V. F. (2015). Fertilizer subsidy programme in Ghana: Evidence of performance after six years of implementation.

Gonzalez, Y. S., Dijkxhoorn, Y., Elings, A., Glover-Tay, J., Koomen, I., van der Maden, E., . . . Obeng, P. (2014). *Vegetables Business Opportunities in Ghana: 2014*. Retrieved from

GSS. (2017). *Ghana Living Standards Survey Round 7 (GLSS7) : Database*. (7). Accra

Ghana Statistical Service.

Islam, M. R. (2018). Sample size and its role in Central Limit Theorem (CLT). *International journal of physics & mathematics, 1*(1), 37-47.

Issahaku, H. (2012). An analysis of the constraints in the tomato value chain. *International Journal of Business and Management Tomorrow, 2*(10), 1-8.

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

Kitinoja, L., Saran, S., Roy, S. K., & Kader, A. A. (2011). Postharvest technology for developing countries: challenges and opportunities in research, outreach and advocacy. *Journal of the Science of Food and Agriculture, 91*(4), 597-603.

Kumi, E. (2017). *Value Chain Analysis Of Tomato In The Kpone-Katamanso District Of Ghana.* University of Ghana,

Melomey, L. D., Danquah, A., Offei, S. K., Ofori, K., Danquah, E., & Osei, M. (2019). Review on Tomato (Solanum lycopersicum, L.) Improvement Programmes in Ghana. *Recent Advances in Tomato Breeding and Production*, 49.

MOFA. (2015). Agriculture in Ghana Facts and Figures: 2016. *Ministry of Food and Agriculture, Ghana*.

Ntow, W. J., Tagoe, L. M., Drechsel, P., & Kelderman, P. (2008). Occupational exposure to pesticides: blood cholinesterase activity in farmers at Akumadan. *The use and fate of pesticides in vegetable-based agroecosystems in Ghana*, 57.

Ogunlela, Y. I., & Mukhtar, A. A. (2009). Gender issues in agriculture and rural development in Nigeria: The role of women. *Humanity & social sciences Journal, 4*(1), 19-30.

Robinson, E. J., & Kolavalli, S. L. (2010a). *The case of tomato in Ghana: Marketing*. Retrieved from

Robinson, E. J., & Kolavalli, S. L. (2010b). *The case of tomato in Ghana: Processing*. Retrieved from

Robinson, E. J., & Kolavalli, S. L. (2010c). *The case of tomato in Ghana: Productivity*. Retrieved from

Rogers, E. M. (2010). *Diffusion of innovations*: Simon and Schuster.

Saran, S., Roy, S., & Kitinoja, L. (2010). *Appropriate postharvest technologies for small scale horticultural farmers and marketers in Sub-Saharan Africa and South Asia-Part 2. Field trial results and identification of research needs for selected crops.* Paper presented at the XXVIII International Horticultural Congress on Science and Horticulture for People (IHC2010): International Symposium on 934.

Shee, A., Mayanja, S., Simba, E., Stathers, T., Bechoff, A., & Bennett, B. (2019). Determinants of postharvest losses along smallholder producers maize and Sweetpotato value chains: an ordered Probit analysis. *Food Security, 11*(5), 1101-1120.

Sibomana, M. S., Workneh, T. S., & Audain, K. (2016). A review of postharvest handling and losses in the fresh tomato supply chain: a focus on Sub-Saharan Africa. *Food Security, 8*(2), 389-404. doi:10.1007/s12571-016-0562-1

Van Asselt, J., Masias, Ian and Kolavalli, Shashidhara. (2018). Competitiveness of the Ghanaian vegetable sector: Findings from a farmer survey. *GSSP Working Paper 47, Washington, DC. International Food Policy Research Institute (IFPRI)*.

Women, U. (2019). THE GENDER GAP IN AGRICULTURAL PRODUCTIVITY IN SUB-SAHARAN AFRICA: CAUSES, COSTS AND SOLUTIONS. *crops, 28*(13.3), 3.0.

Yeaboah, A. K. (2011). *A survey on postharvest handling, preservation and processing methods of tomato (Solanum lycopersicum) in the Dormaa and Tano South Districts of the Brong Ahafo Region of Ghana.*

Appendices

Appendix 1.1 Educational and training background of supply chain actors

Variable	Producers N= 113	Wholesalers N= 25	Retailers N= 39
Education			
No Formal education	17%	12%	15%
Primary education	16%	24%	21%
Junior High School	41%	44%	54%
Senior High School	20%	16%	10%
Tertiary education	6%	4%	0%
Postharvest Management Knowledge			
Yes	35%	12.5%	10.3%
No	70%	87.5%	89.7%

Appendix 1.2 Location of Producers and retailers

Producers N = 113	Percentage	Retailers N = 39	Percentage
Akumadan	12.4%	Agbogbloshie market	25.6%
Afrancho	43.4%	Makola market	43.6%
Tuobodom	32.7%	Madina market	28.2%
Nkenkaasu	11.5%		

Appendix 1.3 Factors influencing the PHL of producers

PHL in kg/acre	PHL in Low rainfall season	PHL in High rainfall season
Producer characteristics		
Gender (Male)	69.9 (56.3)	135.6 (98.1)
Membership of Local Association	-120.1 (56.9)**	-281.3(114.7)**
Log Experience in farming	68.4 (40.3) *	52.8 (71.1)
Location	77.9 (81.6)	21.7 (140.8)
Production characteristics		
Log Farm size	-77.6 (45.2)*	-49.9 (86.4)
Variety (local)	37.2 (75.9)	299.3 (138.5)**
Harvested at full maturity	33.1 (107.2)	-140.3 (135.2)
Postharvest management training	-4.8 (70.1)	5.1 (124.7)
Log Yield	54.8 (43.5)	51.7 (75.4)
_cons	-475.1 (390.2)	-331.2 (704.0)

Obs.	59	59
R-squared	0.237	0.235

**** p<0.01, ** p<0.05, * p<0.1, standard deviations in brackets*

Appendix 1.4 Factors influencing the Interest of Producers to Use a Postharvest Technology

	Interest in using PHM (1=Yes, 0=No)	**Marginal Effect**
Producer characteristics		
Gender (Male)	0.8 (0.9)	0.15
Membership of Local Association	-0.9 (0.7)	-0.15
Log Experience	0.2	0.04
Log Farm size	0.2 (0.6)	0.03
Education	1.0 (0.8)	0.18
Location	2.2 (0.8)**	0.39**
Production characteristics		
Variety (local)	-1.5 (0.9)*	-0.22*
Postharvest Management Training	3.1 (0.9) ***	0.37***
Storage	3.1 (1.1)***	0.20***
Producer perceptions		
Focus on Cost	-2.7 (0.7)***	-0.47***
Support Program to aid adoption	4.3 (2.3)*	0.78*
Adoption of prev. tech	-1.4 (0.7)**	-0.25**
_cons	-4.2	
Pseudo R^2	0.3645	

**** p<0.01, ** p<0.05, * p<0.1, standard deviations in brackets*