

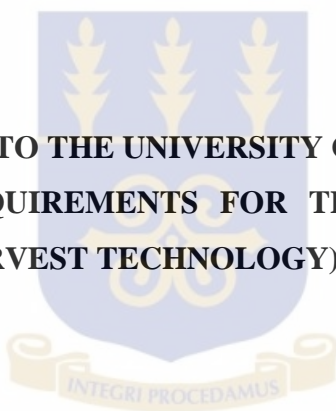
**ASSESSMENT OF LOCALLY PRODUCED WAXING MATERIALS ON THE SHELF
LIFE AND FRUIT QUALITY OF TWO TOMATO VARIETIES (*Solanum lycopersicum*)**

BY

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**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL
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**DEPARTMENT OF CROP SCIENCE
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JULY, 2014

DECLARATION

I hereby declare that, except references to the works of other researchers, which have been duly cited, this work is the result of my own original research and has neither been presented either in whole or in part for the award of any degree.

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.....

Date

DEDICATION

This work is dedicated to Almighty God for giving me precious life up till now. It is also dedicated to my parents Mr. Samuel Osaë Bismark and Mrs. Joyce Osaë Agyapong for their Prayers and support.



ACKNOWLEDGEMENTS

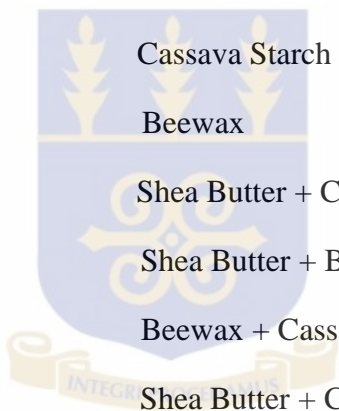
Being confident of this very thing, that the good Lord who has began a good work in you will complete it until the day of Jesus Christ. My first and foremost thanks go to the almighty God for his protection, guidance and blessings upon my life throughout my course of study. I wish to express my appreciation and gratitude to my project supervisors, Dr.Mrs Gloria Essilfie and Prof.John ofosu Anim for their advice; suggestions, constructive comments and guidance which have made this work a success. I would like to express my sincere gratitude to the entire lecturers of the Department of crop science, College of Agriculture and Consumer science, University of Ghana.

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LIST OF ABBREVIATIONS

F.A.O.	Food and Agriculture Organization
USDA	United State Department of Agriculture
MOFA	Ministry of Food and Agriculture
INPhO	Information Network on Post-Harvest Operations
TTA	Total Titrable Acids
TSS	Total Soluble solids
CI	Chilling injury
Ctrl	Control
SB	Shea Butter
CS	Cassava Starch
BW	Beewax
SBCS	Shea Butter + Cassava Starch
SBBW	Shea Butter + Beewax
BWCS	Beewax + Cassava Starch
SBCSBW	Shea Butter + Cassava Starch + Beewax
%WL	Percentage Weight Loss
JSS	Junior Secondary School
JHS	Junior High School.



ABSTRACT

The study was conducted in three phases. Phase one was to assess the postharvest management practices along the tomato value chain in the Fanteakwa District of Ghana. Semi-structured questionnaires were administered randomly to fifty tomato farmers and fifty tomato traders. The value chain of tomatoes as observed in this study, started from pre-harvesting stages and ended with the consumer. Harvesting was done manually and fruits were harvested by majority of farmers when fully ripened. Fruits were harvested mainly in the mornings by most farmers. The farmers also had some knowledge on the postharvest implication of the time of harvest of the produce. All farmers and traders in the study area practiced sorting of fruits into sizes before packaging. The packaging materials that were used included wooden boxes, plastic and cane baskets. Postharvest losses that were incurred started on the farm during harvesting to the point of consumption. The causes of losses were the lack of ready market, lack of storage technology, lack of storage facility, lack of transport for harvested produce, pests and diseases and lack of processing plants. The losses along the tomato postharvest value chain were due to mechanical, rotting (biological) and physiological factors. In all, postharvest management practices involved in the tomato value chain in the district were not adequate to prevent losses. Phase two was to assess the effect of different waxing materials on the quality attributes of tomato fruits. A 2 x 8 factorial experiment layout in complete randomized design with 16 treatment combinations and 3 replication was adopted. The materials that were used for experiment were two (2) varieties of tomatoes (Pectomech and Power Rano) and seven (7) waxing material (shea butter, cassava starch, beeswax, and a combination of shea butter + cassava starch, shea butter + beeswax, cassava starch + beeswax, shea butter + cassava starch + beeswax) and a control. Results from the experiment indicated that all waxing treatments delayed the onset of weight loss, firmness, pH, total soluble solids, and total titrable acidity. The results also suggested that edible wax

coatings delayed the ripening process and colour change of tomato fruits during the storage period and extended the shelf life. However Beewax treatment and its combinations performed better than the other treatments. It was therefore recommended that locally produced wax such as Beewax, shea butter, cassava starch treatments and their combinations could be a good technology for preserving the quality and extending the shelf life of fresh tomato fruit as well as maintaining the physical and chemical properties. Phase three was to assess consumer acceptability of tomato fruits that have been treated with different waxing materials. Semi-structured questionnaires were used to collect data on consumer acceptability of tomato fruits treated with different waxing materials at storage. Sensory analysis was carried out with ten panelists selected from the College of Agriculture and Consumer Science, university of Ghana. The panelists were asked to assess the visual quality of tomatoes that had been treated with different waxing materials. Coded samples per treatment were assessed by each of 10 panelists. A five-point Hedonic scale was used to score sensory attributes of waxed tomatoes. The locally produced waxes (Beewax, Shea butter, Cassava Starch and their combinations) improved some organoleptic and chemical properties such as attractiveness, firmness, smell and overall acceptability of waxed fruits. Generally, for stored tomatoes, consumers preferred waxed fruits to unwaxed fruits. Farmers and traders should be encouraged to use locally available wax materials to coat their produce to maintain the quality.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND

Tomato (*Solanum lycopersicum*.) is a major horticultural crop with an estimated global production of over 129 million metric tons (F.A.O., 2008). It is one of the most widely used vegetables in world (Chapagain and Wiesman, 2004). Tomato is a crop of high economic importance in many countries as it is a relatively short duration crop and gives a high yield (Obeng-Ofori, Ofori-Anim, *et al.*, 2007). It is economically attractive and the area under cultivation is increasing daily in Ghana. Tomato is the most important crop in recently established dry season gardens in the Northern and Upper Regions of Ghana and in the Southern Volta Region. It is also a fairly important cash crop in the outskirts of urban areas in the forest zone (Obeng-Ofori, Ofori-Anim, *et al.*, 2007).

Tomato of the nightshade family is consumed in diverse ways, including raw, as an ingredient in many dishes and sauces and in drinks. The tomato fruit, classified as a vegetable in trade, is a prominent "protective food" (Alam *et al.*, 2007). Tomatoes and tomato-based foods provide a convenient matrix by which nutrients and other health-related food components are supplied to the body. Tomato forms a very important component of food consumed in Ghana and this is obvious in the fact that many Ghanaian dishes have tomatoes as a component ingredient (Tambo and Gbemu, 2010). Tomato is a rich source of vitamin B and phytonutrients, the most abundant in tomatoes are the carotenoids, lycopene being the most prominent, followed by beta-carotene and gamma-carotene, as well as several minor carotenoids (Beecher, 1998). In spite of the modest levels of beta-carotene and gamma-carotene in tomato products, due to their provitamin activity, a high consumption of the vegetable and its products result in a rich supply of vitamin A

in the body. Lycopene, an antioxidant, purportedly fights the free radicals that can interfere with normal cell growth and activity. These free radicals according to Filippone (2006), can potentially lead to cancer, heart disease and premature aging.

Tomato fruits still live and respire after harvesting, however their quality and appearance change during handling. Shelf life is defined as the period in which a product should maintain a predetermined level of quality under specified storage conditions (Ball, 1997). Post-harvest weight change in vegetables is usually due to loss of water through transpiration. This loss of water can lead to wilting and shrivelling, which both reduce market value and consumer acceptability (Ball, 1997). A number of chemical and physical processes take place in vegetables during storage. The quality of most fruits and vegetables is affected by water loss during storage, which depends on the temperature and relative humidity conditions of storage (Perez *et al.*, 2003). Consumers judge the quality of fresh tomatoes by their firmness, color and taste, which are related to ripeness and shelf life. Major losses in the quality and quantity of fresh vegetable and fruit products occur between harvest and consumption (Brooks *et al.*, 2008). These are critically dependent upon three factors: desiccation, physiological process of maturation and senescence and the onset and rate of microbial growth. Hardenburg *et al.* (1986) mentioned that storage under low temperature has been considered the most efficient method to maintain quality of most fruits and vegetables due to its effects on reducing respiration rate, transpiration, ethylene production, ripening, senescence and rot development (Ball, 1997). The effect of storage temperature on physiochemical quality and quantity changes in tomatoes varies with cultivars. The perishability of tomatoes requires the development of technologies that will reduce the postharvest deterioration and extend its shelf life (Gonzalez- Aguilar *et al.*, 2009). The use of

edible coatings or waxing appears to be a promising approach to minimize these problems and preserve the freshness of tomatoes (Gonzalez-Aguilar *et al.*, 2010a).

1.2 PROBLEM STATEMENT

In Ghana, the focus of various stakeholders in the tomato industry has mostly been on improved production capacities of farmers. However, after investing a lot in producing the vegetables, the produce are lost along the postharvest chain through poor handling and preservation. According to Kitinoja and Gorny (2009), postharvest handling of fresh vegetables has a direct link with its shelf life. They reported that, handling starts right from harvesting and estimated losses in developing countries to range from 20% to 50%. The causes of losses were traced to the field, during transport and marketing. Egyir *et al.* (2008) confirmed that fruit losses in Ghana occur mostly during harvesting, packaging, transportation and storage and put the estimate of fruit losses along the postharvest chain at 20.91%. Losses occur at the stages of sorting, packaging, storage, transport and marketing stages of the life of fresh horticultural produce (Kitinoja, 2008).

Losses can be caused by a wide variety of factors, ranging from growing conditions, pre-harvest conditions to handling at the retail level. As observed by Robinson and Kolavalli (2010), in Ghana, the agricultural sector in general and the tomato sector in particular have not met their potential. In this sector, production seasonality, the dominance of rain fed agriculture, high perishability of the vegetable, lack of ready market, lack of reasonable alternative uses of the vegetable and poor pricing are some of the problems faced by farmers. In addition, poor postharvest practices account for the recurrent seasonal postharvest losses of tomatoes.

The traders may also lack the appropriate postharvest skills for prolonging the shelf life of tomatoes in large quantities. The unavailability of preservation techniques in the tomato production areas contributes to the huge amounts of tomatoes lost after harvest. These scenarios are most obviously diminishing the income of tomato farmers at the same time when foreign producers are indirectly financed by the government of Ghana and entrepreneurs through the importation of tomato and tomato products from the foreign market.

1.3 JUSTIFICATION

There are efforts by farmers to increase production of tomatoes to meet the demand of the local market. This notwithstanding, Ghana continues to import several tonnes of fresh and processed tomato into the country. According to Yeboah (2011), the European Union reportedly exported 27, 000 tonnes of preserved tomatoes to Ghana in 2003.

Aryeetey (2006) confirmed that Ghana is second only to Germany as the largest importer of tomato paste, consuming an average of twenty five thousand (25,000) tonnes of tomato paste in a year at a total cost of about \$25 million dollars. Considering that Ghana experiences annual gluts during the major seasons when high percentage of the harvested produce is lost, there is the need to identify causes of such losses and develop better storage techniques to reduce them. Bani *et al.* (2006) revealed that tomato losses incurred along the route alone amounted to 20% from Bolgatanga to Accra. Any degree of postharvest loss of tomatoes has consequences to farmers, traders and consumers. Not only are losses clearly a waste of food, but also represents a similar waste of human effort, farm inputs, livelihoods, investments and scarce resources such as water (World Resource Institute, 1998). Kader, (2005) reported that, the reduction of postharvest losses of perishables is of major importance when striving for improved food security in developing

countries like Ghana. Storage, packaging, transport, handling and preservation techniques are practically non-existent with perishable crops in developing countries and thus allow for considerable loss of produce. As more fresh fruits are needed to supply the growing population in developing countries, more produce is transported to nonproducing areas and more commodities are stored longer to obtain a year round supply. Therefore, post harvest loss prevention technology measures become paramount (Oyekanmi, 2007). The application of new technologies such as irradiation, application of salts, hot water treatments and waxing to extend postharvest life of fresh commodity is needed to delay or reduce post harvest losses. The use of edible coatings appears to be a good alternative. Shahid, *et al.*, (2011) reported that the effect of bee wax coatings on physiological changes in fruits of sweet orange maintained weight loss, firmness, pH, TSS, titratable acidity, TSS/acid ratio, reducing sugars, non-reducing sugars, total sugars and ascorbic acid. Nurul, (2012) revealed that the effect of cassava starch coating on fresh-cut pineapple reduced weight loss, loss of firmness, respiration rate, delayed the change in colour, maintain pH level, total soluble solid as well as quality of the pineapples. The effect of shea butter as a food-grade wax on plantain varieties prolong the shelf life and maintain their sensory qualities. The use of shea butter as a food-grade wax can be further explored since no safety or residual effect is foreseeable (Sugri *et al*, 2010). Mineral oil coating could be a good alternative to preserve the quality and extend the postharvest life of tomato fruit (Gonzalez-Aguilar *et al.*, 2010).

To overcome postharvest losses of tomatoes, there is the need to assess postharvest management practices along the tomato value chain and to develop simple, cost effective and easily adaptable preservation techniques to prolong the shelf life of tomatoes.

1.4 OBJECTIVES

The objectives of the study were to assess the:

1. Postharvest management practices along the tomato value chain in Fanteakwa District.
2. Effect of the different waxing materials on the quality attributes of tomato fruits.
3. Consumer acceptability of tomato fruit that has been treated with different waxing materials.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. BOTANY OF TOMATO

Tomato belongs to the family, Solanaceae and the genus *Lycopersicon*. Norman (1992) has reported that, there are six species of tomatoes, two of which are edible, thus; *Lycopersicon esculentum* Mill, a common tomato and *Lycopersicon pimpinellifolium* Mill, currant tomato. The plant typically grows to 1–3 metres (3–10 ft) in height and has a weak stem that often sprawls over the ground and vines over other plants. It is a perennial in its native habitat, although often grown outdoors in temperate climates as an annual (Smith, 1994) and (Cox, 2000). Tomato plant can be classified to be determinate or indeterminate.

With the determinate plant, the terminal bud ends up in a flower, and growth of axillary shoots is suppressed due to the flowering. Determinate types are annual in all climates. The indeterminate plants have their terminal bud continuing to be vegetative and do not end in flower. Indeterminate types are "tender" perennials, dying annually in temperate climates (they are originally native to tropical highlands), although they can live up to three years in a greenhouse in some cases (Peet *et al*; 2008). Norman (1992) stated that, tomato can have a very extensive root system, but the primary root is usually damaged during transplanting and later a dense lateral root system develops. He added that most root system is located in the first 30cm of the soil. Tomato vines are typically pubescent. The hairs facilitate the vining process, turning into roots wherever the plant gets in contact with the ground and moisture, especially if the vine's connection to its original root has been damaged or severed.

2.2 NUTRITIONAL VALUE OF TOMATOES

Tomatoes are considered one of the best health foods in the world. They abound with essential nutrients such as vitamins and minerals. One cup of cherry tomatoes for example contains approximately 31 calories, 7 grams of carbohydrates, and only 0.5 grams of fat (Bradley, 2003).

Tomatoes are also noted to have a variety of nutrients including fiber and potassium according to the USDA National Nutrient Database (2010). The nutrient value changes based upon the type of tomato. The USDA National Nutrient Database (2010) gives the nutritional content of an average 123g red, ripe raw tomato as follows;

Table 2.1 Nutritional Content of Tomatoes

NUTRIENT	VALUE	NUTRIENT	VALUE
Alpha carotene	124 mcg	Pantothenic acid:	0.109mg
Beta-carotene	552 mcg	Phosphorus	3.0 mg
Calcium	1.2 mg	Potassium	292 mg
Carbohydrate	4.7 g	Protein	1.0 g
Copper	0.073 mg	RAE Vitamin A	52
Dietary Fibre	1.5 g	Riboflavin	0.023 mg
Energy	22.14 kcal	Sodium	6 mg
Fat	0.2g	Thiamin	0.046 mg
Folate (Dietary Folate Equivalents DFE):	18mcg	Total Choline:	8.2 mg
Iron	0.33 mg	Total monosaturated fatty acids:	0.038 g
IU Vitamin A	1025	Total polyunsaturated fatty acids	0.102 g
Lutein + zeaxanthin	151 mcg	Total saturated fatty acid	0.034 g
Lycopene	3165 mcg	Total Sugars	3.23 g
Magnesium	1.4 mg	Vitamin B-6	0.098 mg
Manganese	0.140 mg	Vitamin C (total ascorbic acid):	16.9 mg
Moisture content	116.26 g	Vitamin E - alpha-tocopherol	0.66 mg
Niacin	0.731 mg	Vitamin K (phyloquinone)	9.7 mcg
Zinc	0.21 mg		

Source: USDA National Nutrient Database (2010)

2.3 ANTIOXIDANT PROPERTIES AND OTHER HEALTH BENEFITS OF TOMATOES

Antioxidants are naturally occurring chemicals in many foods, especially fruits and vegetables. Foods rich in antioxidants help protect humans from disease attack and they slow the aging process (Sun *et al.* 2009). According to Keith (1999), over the last 20 years, scientists have been able to demonstrate a common link among the various chronic diseases that currently plague the American people. For example, conditions such as cancer, Alzheimer's disease, rheumatoid arthritis, cardiovascular disease, and cataracts as well as the actual aging process itself may all be, in part, caused by a phenomenon known as oxidative or free radical damage. The term oxidative is used because oxygen is frequently involved (Keith, 1999). He further reported that antioxidants can prevent, stop, or reduce oxidative damage. Lycopene is the pigment responsible for the characteristic deep red colour of ripe tomatoes and their products (Ibitoye *et al.*, 2009).

According to Lindshield *et al.*, (2006) lycopene has earned a plethora of interest for its use as a preventative measure and possible treatment for cardiovascular disease, skin health, eye health, and prostate cancer. Lycopene has also been shown to be the most potent antioxidant produced by the carotenoids pathway (Cox, 2001).

Consumption of fruits and vegetables is linked to lower incidence and lower mortality rates of several types of cancer. These positive effects on human health are attributed in large part to the antioxidant compounds found in high quantities in fruits and vegetables (Cox, 2001). According to Giovannucci (2002), of the 14 carotenoids found in human serum, tomato and tomato products contribute to nine and are the predominant source of about one-half, including lycopene.

However, Dumas *et al.* (2003) reported that tomato cultivars and genotypes vary greatly in lycopene, with processing types generally higher in lycopene than salad or normal types. For instance, Naika *et al.*, (2005) reported that yellow tomatoes have higher vitamin A content than

red tomatoes, but red tomatoes contain more lycopene, the anti-oxidant that may contribute to protection against carcinogenic substances.

Research findings by Arab *et al.*, (2002) further reported that lycopene is likely to also play a role in the prevention of skin and lung cancers respectively. Also, Nkondjock *et al.*, (2005) after a research reported that the dietary intake of lycopene from tomatoes was associated with a 31% reduction in pancreatic cancer risk among men. According to Cox (2001), a University of California Davis survey ranked the tomato as the single most important fruit or vegetable of Western diets in terms of overall source of vitamins and minerals.

Tomatoes are also an excellent source of flavonoids and polyphenols, which are also associated with lower cancer risk (Campbell *et al.*, 2004). It has also been demonstrated that dietary intake of tomatoes especially in the cooked form, are associated with a decreased risk cardiovascular diseases. Cooked tomatoes according Knekt *et al.*, (2002) contain significant amounts of absorbable naringenin and chlorogenic acid. Aside its unique and amazing ability to actually stimulate DNA repair in prostate cells, an increased intake of the flavonoid naringenin has been shown in epidemiological research to be associated with the reduced risk and beneficial effect on vascular diseases and asthma.

Sesso *et al.*, (2003) also found that lycopene might help reduce risk of heart disease. One study found that women who ate at least seven servings a week of tomato-based products had a 30% reduced risk of cardiovascular diseases. Lycopene works synergistically with the other phytochemicals in whole tomatoes to provide a wide range of health benefits. New evidence shows that the protective effects of tomatoes against cancer and cardiovascular disease are due to a combination of lycopene and the other phytonutrients naturally present in the fruit and skin of

the tomato. In other words, you will not obtain all the nutrients if you skin the tomatoes (Heber and Lu, 2002).

Italian researchers *Riso et al.*, (2006) at the University of Milan reported that a daily glass of a commercial tomato juice could lower one of the primary markers of inflammation by almost 35% in less than one month. In addition, in a recent study at the University of the Negev in Beer Sheva, Israel, Engelhard *et al.*, (2006) evaluated the effect of a tomato extract containing lycopene on systolic and diastolic blood pressure in patients with hypertension, as well as the serum lipoproteins, plasma homocysteine and oxidative stress markers. The researchers found that a daily dose of lycopene helped lower blood pressure among 31 men and women with mild hypertension. On average, the subjects' systolic pressure dropped 10 points, while their diastolic pressure, or bottom number, dipped 4 points. From the various uses of tomato, it is evident that tomato passes through several processing stages before consumption. Due to this, a study was conducted to evaluate the stability, isomeric form, bioavailability and *in vivo* antioxidant properties of lycopene. Fortunately, unlike many such nutrients in food, lycopene was found to be somehow stable even after many stages of processing and a considerable length of storage (Honglei *et al.*, 2001). Lycopene content of tomatoes remained unchanged during the multistep processing operations for the production of juice or paste and remained stable for up to 12 months of storage at ambient temperature (Honglei *et al.*, 2001). From these findings, it can be seen that an increase in the consumption of tomatoes comes with a great preventive and curative effect for many common ailments in Ghana.

2.4.0. PRODUCTION OF TOMATOES.

2.4.1. WORLD PRODUCTION OF TOMATOES

Tomato (*Solanum lycopersicum L.*) is one of the most widely grown vegetables in the world (Srinivasan, 2010). It is estimated to be grown on more than 5 million hectares with a production of nearly 129 million tonnes. China tops the chart of tomato growers worldwide. Other high growers include the USA, Turkey and India (Table 2.1). Egypt, Nigeria, Tunisia and Morocco are the leading producers of tomato in Africa (FAOSTAT, 2008).

Table 2.2 World's leading producers of tomato

RANK	AREA	PRODUCTION (MT)
1	China	39938708
2	USA	13718200
3	India	1030300
4	Turkey	10985400
5	Egypt	9204100
6	Italy	5976910
7	Iran	4826400
8	Brazil	3867660
9	Spain	4049750
10	Mexico	2936770
11	Russian federation	1938710
12	Uzbekistan	1930000
13	Nigeria	1701000
14	Ukraine	1492100
15	Greece	1338600
16	Morocco	1312310
17	Chile	977000
18	Tunisia	1170000
19	Syrian Arab republic	1163300
20	Portugal	1147600

Source: FAOSTAT. 2008

From the history of its introduction into European and American cuisine, the importance of tomato has increased over the years. This increased importance in the worldwide market has

consequently been a driving force to expand the acreage and export share for many countries, especially for those located close to the major importing countries (Nicola *et al.*, 2009).

Although tomato requires a relatively cool, dry climate for high yield and better quality, it is adapted to a wide range of climatic conditions from temperate to hot humid tropics (Naika *et al.*, 2009; Srinivasan 2010). Production of tomatoes during the hot-wet season in tropical and subtropical climates suffers a limitation by unfavorable conditions that among others include such factors as high temperature and high incidence of diseases (Nicola *et al.*, 2009).

2.4.2 TOMATO PRODUCTION IN GHANA

Tomato production in Ghana is not uniform and varies from one production area to another. Major tomato growing communities in Ghana are Begoro, Oda and Nsawam, Bolgatanga, Agogo, Kumawu, Akomadan, Derma, Techimantia, Tuobodom, Tanoboase, Amoma and Dormaa Ahenkro, and Accra. In Eastern region, Tomato cultivation begins at Begoro production area from about January 10 to February 10, and harvesting by April. The Oda production areas establish their nurseries in early May and transplanting in June. The minor season begins with Nsawam between late May and early June. (Charles Mensah, 2010 National Best Tomato Farmer).

According to Robinson and Kolavalli (2010), tomato production appears to be falling since 2000. The tomato sector in Ghana has failed to reach its potential, in terms of attaining yields comparable to other countries, the ability to sustain the few processing plants and in terms of improving the livelihoods of the many households involved in tomato production and the tomato commodity chain (Robinson and Kolavalli (2010). This notwithstanding, Ghana continues to import several tonnes of tomato and tomato products into the country. According to Yeboah (2011), the European Union reportedly exported 27, 000 tonnes of preserved tomatoes to Ghana in 2003. Aryeetey (2006) confirmed that Ghana is second only to Germany as the largest

importer of tomato paste, consuming an average of twenty five thousand (25,000) tonnes of tomato paste in a year at a total cost of about \$25 million dollars. According to Aryeetey (2006), in spite of government interventions of establishing or refurbishing of a number of tomato processing plants in recent times. Most Farmers are unable to take advantage of such an interventions as they still prefer planting local varieties. The few who produce commercial varieties are unable to produce the right quantity for commercial agro processing.

Robinson and Kolavalli (2010) report that average yields in Ghana remain low, typically, less than ten tonnes per hectare. They attributed this to production seasonality and high perishability of the produce. Some farmers are unable to sell their tomatoes due to inadequate market access and competition from imports. In the midst of this situation, they upheld that yet other farmers in Ghana have achieved higher tomato yields, production is profitable and many farmers in Ghana continue to choose to grow tomatoes over other crops. The researchers came to this conclusion after surveying 100 tomato growers in three regions over the 2008–2009 seasons: Greater Accra, Brong Ahafo, and Upper East.

2.5.0 POSTHARVEST LOSSES OF TOMATOES

Losses of horticultural produce are a major problem in the post-harvest chain. They can be caused by a wide variety of factors, ranging from growing conditions to handling at retail level. Not only are losses clearly a waste of food, but they also represent a similar waste of human effort, farm inputs, livelihoods, investments and scarce resources such as water. Post-harvest losses for horticultural produce are, however, difficult to measure. In some cases everything harvested by a farmer may end up being sold to consumers. In others, losses or waste may be considerable (Mrema and Rolle, (2002). Post-harvest loss occurs between the completion of

harvest and moment of human consumption. It is thus loss, which happens after separation of the product from the medium and site of immediate growth or production of the product (Cornelius and Obeng-Ofori, 2008). The quality and nutritional value of fresh produce like tomato, is affected by post harvest handling and storage condition (Sablani *et al.*, 2006).

Vegetables are usually harvested when the plant is fresh and high in moisture and are thus distinguished from field crops, which are harvested at the mature stage. This high moisture content of vegetable makes their handling, transportation and marketing a special problem particularly in the tropics. In developing countries, storage, packaging, transport, handling and preservation techniques are practically non-existent with perishable crops and so, this allows for considerable losses of produce. Thus as more fresh fruits are needed to supply the growing population in developing countries, as more produce is transported to nonproducing areas and as more commodities are stored longer to obtain a year round supply, post harvest loss prevention technology measures become paramount (Oyekanmi, 2007).

Post-harvest losses have been highlighted as one of the determinants of the food problems in most developing countries like Nigeria and Ghana (Ojo, 1991; Babalola *et al.*, 2008). Evidence suggests that these losses tend to be the highest in those countries where the need for food is greater; some authorities put post-harvest losses of sweet potatoes, tomatoes, bananas and citrus fruit sometimes as high as fifty percent (FAO, 2002). This means that half of what is produced never reaches the consumer for whom it was grown, and the effort and money required to produce it are lost forever. Reduction in postharvest losses, particularly if it can economically be avoided, would be of great significance to growers and consumers alike.

2.5.1. CAUSES OF POSTHARVEST LOSSES

2.5.1.1. *Primary causes of loss in tomato*

Primary causes are those that directly affect the tomato. They may be classified into the following groups:

- ❖ Microbiological: Microorganisms such as fungi and bacteria, usually directly consume small amounts of the food but they damage the food to the point that it becomes unacceptable because of rotting or other defects (Plate 2.1). Toxic substances elaborated by moulds (known as mycotoxins), cause some food to be discarded hence lost (Cornelius and Obeng-Ofori, 2008).
- ❖ Biological: Consumption of food by rodents, birds and other large animals causes direct disappearance of food. Sometimes the level of contamination of food by their excreta, hair, feathers of animals and birds is so high that the food is condemned for human consumption. Insects cause both weight losses through consumption of the food and quality losses because of their frass, webbing, excreta, heating, and unpleasant odour that impart to the fruit which makes it unpleasant for human consumption (Cornelius and Obeng-Ofori, 2008).



Plate 2.1 Tomatoes destroyed by microorganisms and insects leading to rot and weight loss

- ❖ Physical: Excessive or insufficient heat or cold can spoil foods. Improper atmosphere in closely confined storage containers at times causes losses.
- ❖ Physiological: Natural respiratory loss that occurs in all living organisms account for a significant level of weight loss and the process generates heat. Changes which occur during ripening, senescence, including wilting, and termination of dormancy may increase the susceptibility of the commodity to mechanical damage or infection by pathogens.
- ❖ Mechanical. Bruising, cutting, excessive peeling or trimming of horticultural products are causes of loss (Cornelius and Obeng-Ofori, 2008).

2.5.1.2 Secondary causes of loss in tomato

These losses lead to conditions that encourage a primary cause of loss. They are usually the result of inadequate or nonexistent of capital expenditures, technology and quality control. Some examples are:

- Inadequate harvesting, packaging and handling skills. Improper harvesting of tomato can result in mechanical injury, which predisposes the fruit to pathogens thereby reducing the quality of the produce. Time of harvesting also contributes to high losses; late harvesting exposes the produce to pests, rodents and microorganisms. Inappropriate packaging containers such as wooden crates with rough edges, splinters; protruding nail or staple causes mechanical injury to the produce (Cornelius and Obeng-Ofori, 2008).
- Lack of tomato preservation techniques and processing methods in the production centers contributes to high losses (Plate 2.2) .After harvesting, bruised or damage produce that have been rejected by wholesalers and retailers needs to be processed into canned tomato paste, but because there is no preservation techniques and processing system in the production centers the fruits rot (Cornelius and Obeng-Ofori, 2008).



Plate 2.2 Dumped tomatoes as a result of lack of market, preservation and processing system

- Inadequacy of transportation to move the food to market before it spoils. Bumper harvest can overload the post-harvest handling system or exceed the consumption need and cause excessive wastage (Cornelius and Obeng-Ofori, 2008).

2.6.0 POSTHARVEST MANAGEMENT PRACTICES

2.6.1 HARVESTING

Postharvest activities include harvesting, sorting, processing, storage, packaging, transportation and marketing (Mrema and Rolle, 2002). The principles that dictate at which stage of maturity a fruit or vegetable should be harvested are crucial to its subsequent storage, marketable life and quality. Postharvest physiologists distinguish three stages in the life span of fruits and vegetables: maturation, ripening and senescence. Maturation is indicative of the fruit being ready for harvest (FAO, 2008). Harvesting marks the end of the growth cycle of tomatoes and the beginning of a series of stages of very important activities that ensure that the consumer gets the vegetable in the preferred state and at the best of desired quality. Harvesting fresh-market tomatoes is labor intensive and requires multiple pickings (Orzolek *et al.*, 2006). According to Orzolek *et al.*, (2006), tomatoes for the wholesale market should usually be picked at the mature green to breaker stage to prevent the fruit from becoming overripe during long transportation/shipping and handling. They recommend leaving tomatoes on the vine to ripen if they can be brought to market quickly and in good condition and that, it is when market is available that tomatoes should be vine-ripe before harvesting.

In Ghana, fresh market tomatoes are usually harvested by hand with harvesting operation varying among growers. However, where there is unavailable and poor access to markets, tomato farmers leave their produce in the fields to rot. For the harvesting operation, Kitinoja (2008) recommends the use of plastic buckets for harvesting fruits that are easily crushed, such as tomatoes. These should be smooth without any sharp edges that can damage the produce.

In harvesting, Hurst (2010) advises that a good harvesting practices especially in picking high quality tomatoes, since the riper the tomato, the more susceptible it is to bruising. He also

advises harvest crews to carefully place fruits into picking containers instead of dropping them since research has demonstrated that a drop of more than 6 inches onto a hard surface can cause internal bruising that is not evident until after the tomato is cut open. He further advises against overloading of bins. He explains that extreme tomato weight will provide a force of compression to cause bruise damage to the tomatoes. He also recommends shading of harvested tomatoes to minimize heating-up while waiting to be taken to the packing house based on the research findings that, bulk bin tomatoes held in the hot sun for just one hour can be as high as 4⁰ C (25⁰F) warmer than fruit held in the shade and that field heat can speed up breakdown.

2.6.2 POSTHARVEST HANDLING

According to Kitinoja and Gorny (2009), postharvest handling of fresh vegetables has a direct link with its shelf life. They reported that, handling starts right from harvesting and put estimates of losses in developing countries in the range of 20% to 50% tracing causes of losses to the field, during transport and marketing. Tomatoes are highly perishable and very susceptible to mechanical damage with poor handling and transportation (Bani *et al.*, 2006).

Most often also, losses of fresh vegetables occur along the long chain of supply from the producer to the consumer. Losses occur at the stages of sorting, packaging, storage, transport and marketing stages of the life of fresh horticultural produce (Kitinoja, 2008). As a remedy, Kitinoja and Gorny (2009) recommended that when handling fresh produce at its market destination, it is important to avoid rough handling, minimize the number of handling steps and strictly follow a temperature and relative humidity management. Stacking of non uniform containers should also be done with care to prevent collapse of weaker packages and heavier cartons should always be placed at the bottom of a stack (Kitinoja and Gorny, 2009).

Bani *et al.* (2006) in a research conducted in Ghana to assess losses of tomatoes from Bolgatanga to Accra revealed that losses along the route alone amounted to 20%. Losses of horticultural produce are a major problem in the post-harvest chain. They can be caused by a wide variety of factors, ranging from growing conditions to handling at retail level. Not only are losses clearly a waste of food, but they also represent a similar waste of human effort, farm inputs, livelihoods, investments and scarce resources such as water (World Resource Institute, 1998). Kitinoja (2008) summarizes the various stages and causes of losses with the diagram in Figure 2. 1.

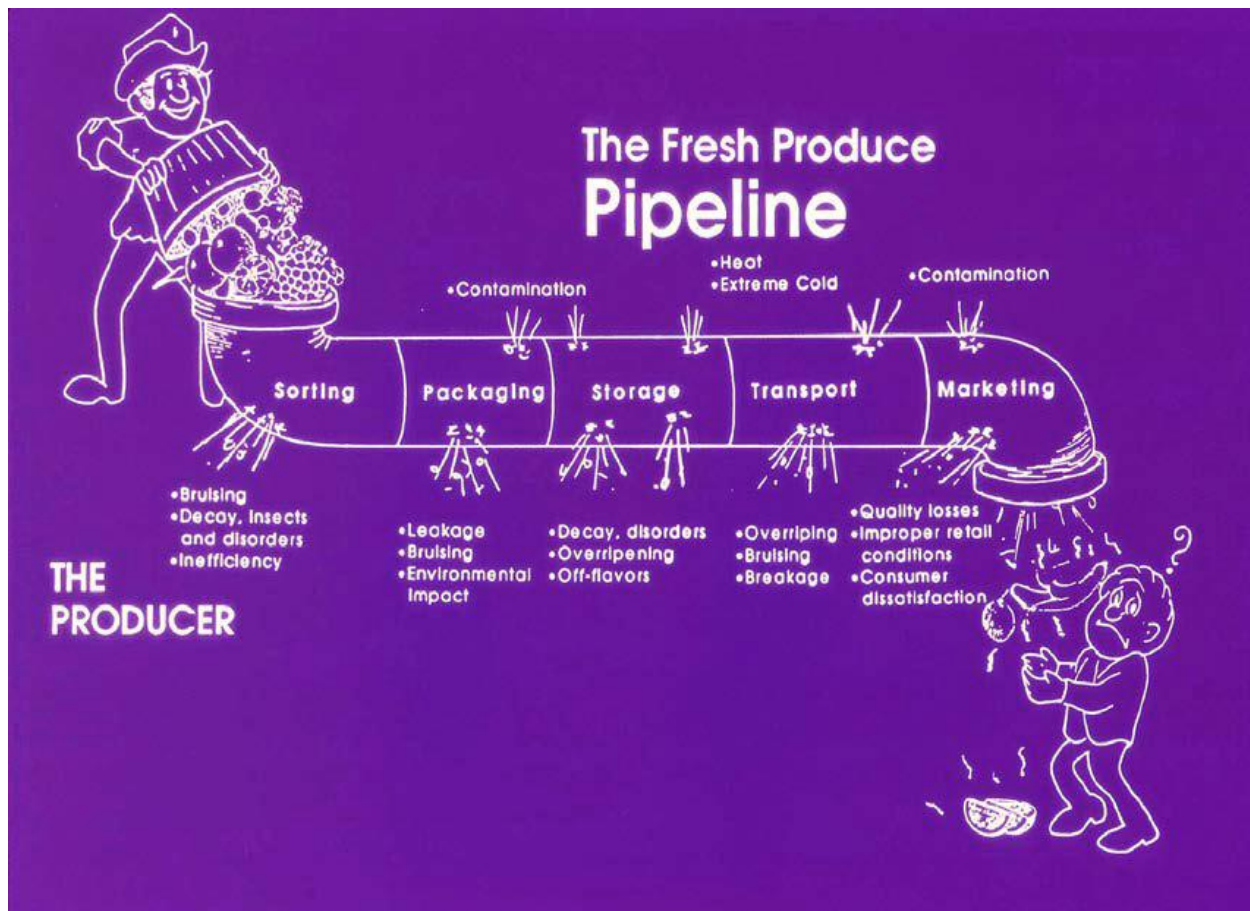


Figure 2.1 Postharvest losses of harvested horticultural produce

Source: Kitinoja: (2008).

2.6.3. PACKAGING

Tomato fruit are usually packed in wooden boxes, plastic crates, plastic bowls and cane basket especially during transportation. The use of appropriate packaging is an important physical control method of protecting produce from pest infestation and damage in order to reduce losses and ensure that produce reaches the consumer in the best possible condition (Cornelius and Obeng-Ofori, 2008). For local markets, the fruits are packed in baskets, cardboard boxes, wooden crates and transported over long distances, especially from the Northern parts of Ghana to the attractive markets in the south (Obeng-Ofori *et al.*, 2007) According to FAO (2008) and Nasrin *et al.* (2008) fruits have soft cover which are easily destructed and easily attacked by microbes which bring deterioration. Packages should be designed to have sufficient openings for allowing air ventilation to the fruits. However, the cost of packaging materials has escalated sharply in recent years. This has promoted the use of lightweight containers that can be easily damaged by handling (Vitroy, 2008).

2.6.4. STORAGE

Storage is the process of keeping produce at the appropriate environment and structure to maintain the quality at a specific period of time. In developing countries, there is lack of storage facilities and technology on on-farm or at wholesale or retail markets. The very few existing on-farm facilities have inadequate ventilation and cooling. In addition to that they are over-loaded with commodities most of which require different temperature and relative humidity (Kitinoja and Gorny, 2009). There are few key factors to consider when storing fresh produce because some cultivars have a naturally longer storage potential than others of the same commodity. FAO (2008) reported that when stored at 10°C with the optimum humidity of about 80%, green tomatoes can be stored for 16 - 24 weeks. In another report, Ashby (2000) recommend 13°C to

21°C and a relative humidity of between 90 to 95% has the best transport conditions for green-mature tomatoes. However in Ghana most people do not store tomatoes when it is green matured but rather red ripe. Red ripe tomatoes can be stored at ambient temperature for a period of up to 7 days. It is generally accepted that for longer period ripe tomatoes can be stored at a temperature of 10-15°C and 85-95 relative humidity (Castro *et al.*, 2005).

2.6.5 TRANSPORT

Tomatoes are highly perishable in nature hence efficient means of transportation is necessary. Tomato is transported to the near-by towns and city market only by road. During transportation, bumping and vibration can damage tomatoes. Cushioning the produce in the container can reduce these causes of damage (Obeng-Ofori *et al.*, 2007). According to Yabalola *et al.*, (2008), open truck vehicle and taxis are appropriate since they don't expose the fruit to direct solar radiation which will cause premature senescence and subsequent reduction in shelf life. It can, however, cause mechanical injury and internal damage as result of vibration during transportation which lowers shelf life and market value. The mode of transport also contributes to mechanical and physiological damage of fruits. Meanwhile the accumulation of unarranged packed fresh fruit in tracks during transportation may also lead to increased heat due to metabolic reaction of the cells and it may accelerate their mechanical damage. The breakdowns of vehicles can be a significant cause of losses in some areas as perishable produce can be left in the sun for a day or more while repairs are carried out. The existence of poor infrastructure, poor nature of roads and transportation facilities causes up to 40% losses (Mehmood *et al.*, 2011).

2.6.6 MARKETING

Six basic marketing alternatives are available to the tomato grower: wholesale markets, cooperatives, local retailers, roadside stands, pick-your-own operations and processing firms (Orzolek *et al.*, 2006). Marketing cooperatives generally use a daily-pooled cost and price, which spread price fluctuations over all participating producers.

Fresh and processed produce can be marketed on the farm, at the farm gate, locally or regionally via wholesale or retail operations or through exports to other countries. When deciding how to market your fresh and processed produce, each postharvest handling step taken provides an opportunity to make additional profits (Kitinoja, 2004). The difference in product preferences shows the degree of difficulty likely to be encountered by exporters to the American market and the need to train farmers to be able to produce for the international market. As clearly indicated, in both markets, post-harvest handling is key to quality.

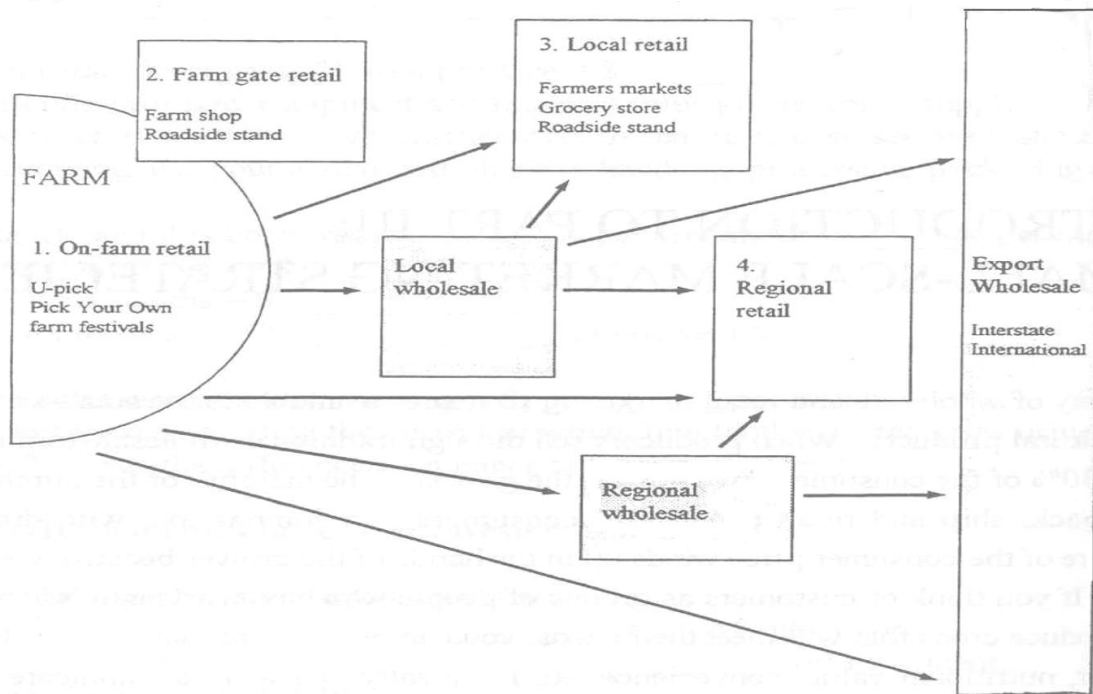


Figure 2.2 Market options available to producers of fresh tomatoes

Source: Kitinoja and Gorny: 1999.

2.6.7 PRESERVATION OF TOMATOES

On preservation, Gonzalez-Aguilar *et al.*, (2010) recommend that the use of edible coatings or waxing in conjunction with low temperature storage appears to be a promising approach to preserve the freshness of tomatoes. Postharvest handling technical bulletin No 9, (2003) reported that a thin water-wax emulsion spray coating is normally applied to tomato fruit as a final step in the cleaning process and to improve its quality. Waxing the tomato fruit will enhance its appearance and make it glossier. Waxing can reduce fruit shriveling and increase market life. Waxing also provides lubrication to the fruit surface that reduces rubbing injury during transit. Kitinoja and Gorny (2009) suggest the use of brine or vinegar to preserve vegetables such as the

tomato. Due to the acidic nature of vinegar, there is no need for further processing if it is decanted into sterilized containers before being filled with the tomatoes.

Ashby (2005) described a simple home-drying method for stewing tomatoes. Ripe tomatoes are steamed or dipped into boiling water to loosen skin, chilled in cold water, peeled and cut into sections about $\frac{3}{4}$ inch wide, or slice. These are blanched for three minutes and dried in the dehydrator for 10 – 18 minutes or twice this time using the conventional oven. Other preservation methods are described by the Food and Agriculture Organization (FAO) and the Information Network on Post-Harvest Operations (INPhO). FAO and INPhO (1998) describe pulping, the drying and the peeled tomato preservation methods.

2.7.0 WAXING AND SURFACE EDIBLE COATINGS

Waxing is the process of covering fruits and vegetables such as apples, garden eggs, watermelon, cucumbers and tomatoes with artificial and natural waxing material. Natural Waxing materials include Beeswax, Carnauba Wax, Candelilla Wax, Montan Wax, Palm Wax, Rapeseed Wax, Soy Wax, Rice Bran Wax, Olive Wax, Sunflower Wax and Coconut Wax, while the artificial waxing materials include Petroleum wax, Paraffin wax oil, etc. The reasons for waxing are to prevent water loss, thus retard shrinkage and spoilage and also to improve appearance (Keith Thompson, 2003). A thin water-wax emulsion spray coating is normally applied to tomato fruit as a final step in the cleaning process and to improve its quality. Waxing the tomato fruit will enhance its appearance and make it glossier. Waxing can reduce fruit shriveling and increase market life. Waxing also provides lubrication to the fruit surface that reduces rubbing injury during transit. (Postharvest handling technical bulletin No 9, 2003).

The use of edible coatings in conjunction with low temperature storage appears to be a promising approach to preserve the freshness of tomatoes (Gonzalez-Aguilar *et al.*, 2010a). The mechanism by which edible coatings preserve fruits and vegetables is the establishment of a modified atmosphere around the product, which serves as a partial barrier to Oxygen (O₂) and Carbon dioxide (CO₂), water vapor and aroma compounds, decreasing the respiration rate of the fruit, water loss, preserving texture and flavor (Olivas and Barbosa-Canovas, 2008).

Edible coatings are composed of hydrocolloids (polysaccharides or proteins), hydrophobic compounds (lipids or waxes) or a combination of both (composite coatings) that may enhance the coating properties for optimal handling (Espino-Diaz *et al.*, 2010). Several studies have reported the use of edible coatings for fruit and vegetable preservation during storage. Today, many edible coatings are available, mainly to preserve the quality of citrus and apples and to a lesser extent, mangos, papayas, pomegranates, cherries, avocados, cantaloupes and tomatoes, among others (Olivas *et al.*, 2008). Waxing, acting as semi permeable barriers, may be an effective method to alleviate chilling injury (Meng *et al.*, 2008; Ahmed *et al.*, 2009). Chien *et al.*, (2007) also reported that the effect of waxing on tomato fruit could improve firmness, titratable acidity, ascorbic acidity and the water content.

2.7.1 TYPES OF FOOD GRADE WAX

Waxes are not a new phenomenon, as they have been used domestically for over 60 years, on a wide variety of fruits and vegetables. Waxes are derived from a variety of sources and are a cross combination of natural and synthetic ingredients (www.Star-K.org)

Several different raw materials are used as a base for formulating food-grade waxes. The most commonly used materials are paraffin, carnauba, shellac, and polyethylene. Less frequently used

wax bases include beeswax and candelilla wax (Postharvest handling technical bulletin No 33, 2004). Petroleum based waxes including paraffin, mineral oil, and polyethylene. These waxes are commonly used on melons, stone fruits, tropical fruits and in a variety of vegetables (www.Star-K.org). Each of these raw materials has unique and different properties which determine its shine, firmness, gas exchange and other physical characteristics. The raw materials are mixed with water and wetting agents to provide a thin continuous coating. The waxes available commercially are already pre-mixed and ready for immediate application. The amount of wax applied to each individual fruit or vegetable is very small. For example, one gallon of liquid Carnuba, shellac, or polyethylene based wax applied with a roller brush will cover up to 75,000 tomatoes, and up to 95,000 peppers or cucumbers. The amount of individual ground provisions covered by paraffin wax will be significantly less due to the thicker wax coating and the larger surface area of the products (Postharvest handling technical bulletin No 33, 2004).

2.7.2 IMPORTANCE OF WAXING

(a) Improved Appearance

According to postharvest handling technical bulletin No. 9, (2003), waxing of tomato fruit will enhance its appearance and make it glossier. Fruits and vegetables that are waxed generally have more shine and brilliance. They also retain their color and fresh appearance for a longer period. This is desirable from a marketing standpoint, as buyers initially judge the acceptability of a product based on external appearance. Waxing can also improve the internal color of certain commodities (Postharvest handling technical bulletin No 33, 2004).

(b) Less Moisture Loss

Postharvest handling technical bulletin No. 33, (2004) reported that all fruits and vegetables such as tomatoes are covered naturally in a cuticle which is a barrier to moisture loss. However, some water vapor can move through the pores, cuticle and micro-cracks in the cuticle.

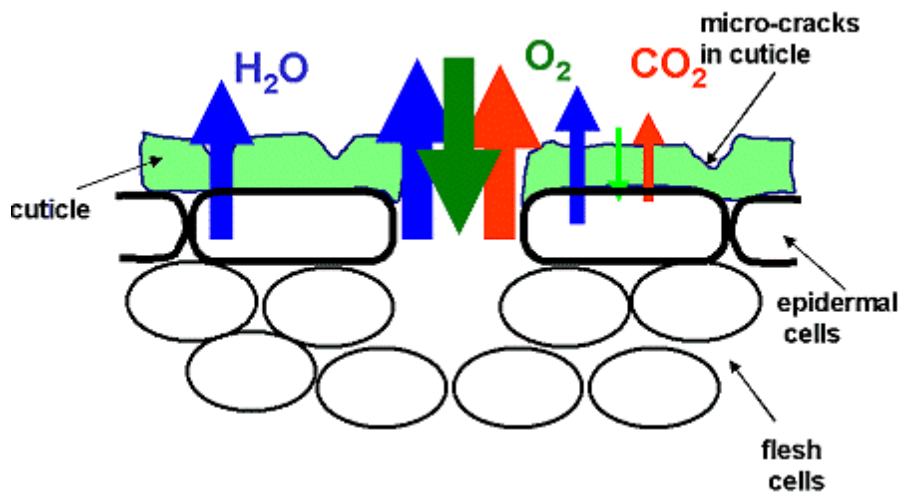


Figure 2. 3 Showing the movement of O₂, CO₂ and H₂O to and from the cuticle of tomato fruit

Source: Postharvest handling technical bulletin No 33, 2004

During the process of waxing, a tightly adhering thin film of the coating substance is applied to the surface of the fruit. The wax coating blocks the pores in the cuticle, which significantly reduces the amount of water vapor loss. The amount of moisture loss typically lowers the grade of the product or makes it completely unmarketable. The longer produce is expected to be stored, the more important waxing becomes in reducing weight loss. Application of a thin layer of wax coating can reduce product weight loss by 30 to 40%. Undesirable textural changes and pithiness are reduced or avoided when waxing is done to reduce moisture losses. Waxing provides a

barrier to reduce such unwanted moisture losses (Postharvest handling technical bulletin No 33, 2004).

(c) *Less Economic Loss*

Water is the principal component of all fresh fruits and vegetables. It usually constitutes between 80 to 90% of a product's fresh weight. Once harvested, the fresh product begins to lose moisture from the processes of transpiration (evaporation of water) and respiration. This results in product weight loss, which is undesirable from an economic standpoint. Growers often sell their fresh products such as tomato fruit based on weight, and will obtain less economic return with increasing amounts of weight loss (Postharvest handling technical bulletin No 33, 2004).

(d) *Reduced Postharvest Decay*

Waxing establishes a barrier against the entrance of fungi, bacterial and other pathogens into the product. Postharvest pathogens typically require a film of free moisture on the product's skin to grow. Waxing creates a hydrophobic (non-water compatible) surface which is not conducive to pathogen growth and development. A fungicide can also be added to the wax to provide added protection against decay (Postharvest handling technical bulletin No 33, 2004).

(e) *Longer Postharvest Life*

According to Postharvest handling technical bulletin No. 33 (2004) fruits and vegetables such as tomatoes are living organisms that continue to respire after harvest. Waxing creates a modified atmosphere inside the product in which the oxygen content is decreased and the carbon dioxide content is increased. This results in a reduction in the product's respiration rate and an increase

in postharvest life. A prolonged postharvest life allows for an extension in the marketing period for the farmer and trader.

(f) Less Susceptibility to Chilling Injury

Fruits and vegetables of tropical origin such as tomatoes are susceptible to chilling injury (CI), which is a type of physiological injury that occurs at low temperatures. The amount of CI depends on the temperature and duration of exposure to the low temperature. It occurs between 13°C (56°F) and 0°C (32°F), depending on crop. Waxing reduces the severity of CI and allows for storage of CI-sensitive commodities at slightly lower temperatures without incurring damage. However, waxing does not eliminate CI on the susceptible commodities (Postharvest handling technical bulletin No 33, 2004).

2.7.3. WAX APPLICATION METHODS

The tomato fruit are normally waxed by manual rubbing and dipping / submergence.

Manual Rubbing

Liquid waxes such as Shea butter, coconut oil and palm kernel oil will be applied by manually rubbing the tomato fruit and smearing the wax evenly over the surface. A soft absorbent cloth or fine bristled brush will be used to smear the wax on the fruits. After application, the tomato fruit will be left to air dry for about 15 minutes before packing. (Postharvest handling technical bulletin No 33, 2004).

Dipping / Submergence

The tomato fruit is typically applied as a brief dip or submergence in a bath of melted wax such as beeswax, paraffin and shea butter. Upon removal from the melted solution, the wax solidifies

almost instantaneously. The tomato fruit will be ready for packing within a minute after dipping. (Postharvest handling technical bulletin No 33, 2004).

2.8.0. FRUIT QUALITY ATTRIBUTES

2.8.1. WEIGHT LOSS

Weight (water) loss may differ in horticultural crops depending on their variety, size, texture, storage method and length of storage. Quality of most fruits and vegetables is affected by weight (water) loss during storage, which depends on the temperature and relative humidity conditions (Perez *et al.*, 2003). Wilson *et al.*, (1999) reported that Transpiration is a major cause of deterioration because it results in direct quantitative loss (loss of weight) and Weight (water) loss is the principal cause of fruit softening and shriveling. Respiration is a central process in living cells that mediates the release of energy through the breakdown of carbon compounds and this gives an indication of the overall metabolism of the plant part which utilizes the plant product as its substrate thereby leading to weight loss and shriveling. The respiration rate can be used to predict the loss of weight from a produce. In marketing systems based on weight, respiration losses of carbon represents weight loss in the product hence a decrease in value (Kays, 1991). Maalekuu *et al.*, (2004) reported that the effect of weight loss in sweet pepper and other vegetables cause damage to fruit appearance and subsequent loss of market value.

2.8.2. FRUIT FIRMNESS

Firmness is a critical quality character because it determines whether or not fruit can be transported or shipped to distant markets without deteriorating. Tomato fruit soften as they develop from immature green to full red colour (Hanson, 2001).

The firmness is a criterion often used to evaluate fruit quality as it is directly related to fruit development, maturity, ripening and storage potential. It is also related to the likelihood of bruising when fruits are subjected to impact during handling (Lesage and Destain, 1996). Dobrzanski and Rybezyski (1998) considered firmness to be the principal characteristics of fruit, important for quality, harvest, maturity, and storage and shelf- life. High quality fruits have a firm appearance, uniform and shiny colour, without signs of injury, shriveling or decay (Sargent and Moretti, 2002). Bosland, (1993) stated that, genetic background, growing conditions and fruit constitution at the time of testing (degree of ripeness, size, post-harvest handling and internal temperature) affect fruit firmness. Changes in firmness are highly correlated with surface appearance characteristics of tomatoes which related to colour, shape and sense of feel to firmness. Loss of pulp firmness during ripening varies with cultivar or hybrid. It is often inversely related to ripening, implying that, as ripening progressed, pulp firmness declined (Hibler and Hardy, 1994). Lownds *et al.*, (1993) found a very pronounced decrease in fruit firmness to be associated with increase in weight loss during prolonged storage of pepper and other vegetables. It has also been established that the temperature at the time of testing critically affects firmness of both raw and processed products (Bourne, 1982; 1986), therefore measurements should be conducted in a narrow temperature range.

2.8.3 pH

The term pH is used to express the concentration of free H_3O^+ in a sample and results from dissociation of the acids present. pH is defined as the negative logarithm of the hydrogen ion concentration, and can span a range of 14 orders of magnitude. $pH = -\log [H^+]$. A lower pH value indicates a more acidic sample due to freer H_3O^+ , and a higher pH value indicates a more basic sample.

pH is the measure of the strength of the acids. Shahid *et al.* (2011), reported that increase in pH in wax treated fruits might be due to high rate of metabolic activities, hence acidity decreased but pH increased and result in high TSS contents. An accurate pH measurement is usually determined instrumentally with a pH meter. According to Hanson (2001), most acid in the fruit is contained in the locules and acidity ranges in pH from 4 - 5 in tomato. A pH < 4.5 is required for processed tomato because microbial growth is inhibited.

2.8.4 TOTAL SOLUBLE SOLIDS

The soluble solids content is determined by refractometer, which measures the percent of sugar (sucrose) by weight at the temperature indicated on the instrument. The total soluble solids acts as a rough index of the amount of sugars present in fruits. It is the amount of sugar and soluble minerals present in fruits and vegetables. According to Alleyne and Clark (1997), the soluble solid content is a parameter determinant of fruit quality and is an important criterion for selecting tomato genotypes for processing and canning. Sugars constitute 80-85 per cent of soluble solids. The total soluble solids increase during ripening due to degradation of polysaccharides to simple sugars thereby causing a rise in total soluble solids (Naik *et al.*, 1993).

Soluble solids content vary between cultivars and between stages of ripeness. For example, in some hybrids of banana soluble solids contents increase to a peak and then decline (the drop in total soluble solids may be due to the conversion of sugar in pulp alcohol), while in others, total soluble solids continue to increase with ripening (Hibler and Hardy, 1994). Studies have associated high consumer acceptance with high soluble solids concentration (SSC) in many commodities (Kader, 1994). According to Artes *et al.*, (1999), the increment of soluble solids is caused by the biosynthesis processes or degradation of polysaccharides during maturity. Total

soluble solid content increases with ripening, but may increase or decrease during storage as carbohydrates are utilized during fruit respiration and may increase due to the action of sucrose - phosphate syntheses which is activated by the ripening process itself, by ethylene, and by cool storage, (Mitchell *et al.*, 1991). Moreover, Syamal (1991) reported that the total soluble solids increase during ripening. During the normal ripening, the Total soluble solid tend to increase through the stages of maturity. Sugars, acids and their interactive are important for sweetness, sourness and overall flavour intensity in tomatoes. Fruit with high dry matter content usually also have higher soluble solids, and thus have better taste and flavour (Hao *et al.*, 2000b).

2.8.5. EXTERNAL COLOUR

The appearance of tomato is greatly influenced by the presence and magnitude of defects. Kays, (1999) indicated that, general appearance of fruits plays an important role in making purchasing decisions and is affected mainly by fruits firmness, weight loss and decay incidence. Tomato colour, a factor for general appearance is another important factor in the consumer preference of tomatoes (Batu, 2003). Colour in tomato is the most important external characteristic to assess ripeness and postharvest life, and is a major factor in the consumer's purchase decision. Red colour is the result of chlorophyll degradation as well as synthesis of lycopene and other carotenoids, as chloroplasts are converted into chromoplasts (Fraser *et al.*, 1994).

2.8.6. TOTAL TITRABLE ACIDITY

Acidity in fruits is an important factor in determining maturity. Titratable acidity gives the total or potential acidity, rather than indicating the number of free protons in any particular sample. It is a measure of all aggregate acids and sum of all volatile and fixed acids. Titratable acidity

(TA), also referred to as total acidity, measures the total acid content in a food or beverage system and is determined by titration of the acids in the food system with a standard base. According to Hu et al., (2011), wax treatment reduced titratable acidity of pineapple kept under cold storage conditions by approximately 6% and 5 % compared with the control at 21 days of storage. Similar works by Jiang and Li (2001) showed that the effect of wax coating on longan fruit decrease titratable acidity decreased during storage. A high acid content imparts a sour taste that is desirable in some countries. Over the years it has been shown that titratable acidity and pH contribute to the acid taste.

2.8.7 SHELF LIFE

Shelf life is defined as the period in which a product should maintain a predetermined level of quality under specified storage condition. Fruits shelf life during storage is an important feature from a producer's and a distributor's point of view, allowing the determination of risks arising from the loss of commercial value of fresh fruit in trade turnover (Radajewska and Borowiak, 2002). Tomato can be stored at ambient temperature for a period of up to 7 days. The shelf life is a period of time which starts from harvesting and extends up to the start of rotting of fruits (Mondal, 2000). Gonzalez-Aguilar *et al.*, (2010a), reported that the use of a mineral oil treatment preserved the quality of tomato fruit to the greatest extent and concluded that mineral oil wax could be a good alternative for preserving the quality and extending the shelf life of fresh tomato fruit. Shahid *et al.*, (2011) also reported that the effect of bee wax coating were very effective in improving the overall quality and extending the shelf life of sweet orange fruits at room temperature. This result is in line with Nurul, (2012) who revealed that the effect of cassava

starch coating on fresh- cut pineapple delayed the change in colour, maintain quality of the pineapples and prolong the storage life.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 STUDY LOCATION

The study was conducted from July 2013 to June 2014 in the Fanteakwa District and the Physiology Laboratory of the Department of Crop Science, University of Ghana. Fanteakwa District is one of the Twenty-six (26) districts in the Eastern Region of Ghana with Begoro as the capital. It is located exactly in the middle of the Eastern Region with a total land area of 1150 sq. km. The communities selected in the district for the study included Begoro, Akoradako, Nkankama, Obooho, Onuku and Ahomahomaso.

3.2 RESEARCH METHODOLOGY

This section outlines the approaches that were adopted in the conduct of the study to achieve the research objectives.

3.2.1 Assessing the postharvest management practices along the tomato value chain in Fanteakwa District

Semi- structured questionnaires were developed and administered to fifty (50) farmers and fifty (50) traders. Simple random sampling was used in selecting the respondents. Information on demographic characteristics, management practices (harvesting, packaging, storage, and transportation), perception of farmers, and traders on waxing of tomato fruits after harvest, knowledge about post-harvest losses and causes of these losses were collected. Field observations were recorded in the form of pictures.

3.2.2 *Assessing the quality changes of tomato fruit that has been treated with different waxing materials*

The experiment was conducted in the Physiology Laboratory of the Department Crop Science, in the University of Ghana. The materials used for the experiment were two (2) varieties of tomatoes (Pectomech and Power Rano) and seven (7) waxing materials (shea butter, cassava starch, beeswax, and a combination shea butter + cassava starch, shea butter + beeswax, cassava starch + beeswax, shea butter + cassava starch + beeswax) and a control.

Table 3.1 DISCRPTION OF MATERIALS

<i>TREATMENTS</i>		<i>RATIOS</i>
T₀	Control	-
T₁	Shea butter	-
T₂	Cassava starch	-
T₃	Beeswax	-
T₄	Shea butter + Cassava starch	1:1
T₅	Shea butter + Beeswax	1:1
T₆	Beeswax + Cassava starch	1:1
T₇	Shea butter + Cassava starch + Beeswax	1:1:1
V₁	Pectomech	-
V₂	Power Rano	-

A 2 x 8 factorial experiment layout in complete randomized design with 16 treatment combinations was adopted. The tomato varieties were grown under farmers' condition in Fanteakwa District. The fruits were harvested at the physiological stage of maturity and transported to the laboratory of the Department of Crop Science. The fruits were sorted to

remove diseased or bruised ones, washed using chlorinated water to remove dirt, spray residues, disease spores and air dried under room conditions. The cleaned and dried fruits were divided into 16 lots each containing 30 fruits. Each treatment was replicated three times.

3.2.2.1. Wax application method

The tomato fruits were briefly dipped or submerged completely in a bath of melted wax such as beeswax and shea butter at a temperature of 45°C. Upon removal, the beeswax and shea butter solidified almost immediately. The tomato fruit was ready for packing within a minute after dipping. The cassava starch slurry was prepared by mixing 400g of cassava starch with 1.5 liters of water. This solution was then heated up to 50°C while continuously stirring until the starch was gelatinized. The cooked starch was allowed to cool and the fruits were dipped in it completely for 30 seconds to ensure that the fruit was completely covered with the starch. The coated fruits were allowed to air dry after the wax application. All lots of fruits were packed according to the experimental layout and stored at room temperature in the laboratory. The concentrations of wax used were by volume in a ratio of 1:1 and 1:1:1 for the treatment combinations, respectively.

3.3.0 Data collection

Data on randomly selected fruits in each treatment per replication was recorded at 0, 5, 10, 15, and 20 days of storage during the experiment on the following quality indices (Gonzalez Aguilar *et al.*, 2009).

3.3.1. Weight loss (%)

For the determination of weight loss during storage, 3 fruits were marked at the start of experiment from each treatment and kept separate for periodic weighing using an electronic balance (Park *et al.*, 1994). The percent weight loss was calculated as follows:

$$\text{Percentage weight loss} = \frac{\text{Weight of fresh fruit (g)} - \text{weight after interval (g)}}{\text{Weight of fresh fruits (g)}} \times 100$$

3.3.2 Firmness

Firmness of fruits was measured by using a penetrometer (Model FT327-8mm). Three tomato fruits were sampled randomly from each treatment and their firmness was determined according to the manufacturer's instructions.

3.3.3 pH of fruits

The pH of fruit juice was measured by using a digital pH meter (Symphony, Model SB70P). Three fruits were randomly sampled from each unit and pH values of the juice were measured according to Association of Official Analytic Chemist (AOAC) method (1990).

3.3.4 Total Soluble Solids

Total soluble solids were determined for three fruits using a digital refractometer at room temperature. The refractometer was calibrated with distilled water and 3 drops of juice from the homogenized sample were placed on the prism of the refractometer and the reading taken. The determinations were done in triplicate and the mean values were recorded.

3.3.5 External Colour

Measurements of skin colour were taken from each fruit (three fruits per treatment), using a Minolta colorimeter (model CR-300; Minolta Corp., Ramsey, NJ, USA). The values were obtained on a CIELAB scale (L*, a*, b*). The L*, a*, b* values represent luminosity, redness and yellowness of the fruit, respectively. To obtain the real colour changes of the fruit, a* values were analyzed for the external colour and expressed in percentage.

3.3.6 Total Titrable Acidity

Three fruits from each treatment were homogenized in 100mls of distilled water in a kitchen blender. The homogenized solution was filtered through a muslin cloth. Ten milliliters of the filtrate was transferred into a 125mls conical flask and 100mls of distilled water was added to the filtrate. Three drops of phenolphthalein indicator was added to the filtrate and titrated against the alkaline, 0.1N of NaOH until the final colour turned pink. The titre values were recorded and the percentage citric acid was calculated using the method described by Mitcham *et al.*, (1996).

$$\% \text{ Acid} = \frac{\text{Mls NaOH} \times \text{Normality (NaOH)} \times 0.064^*}{\text{Volume of Sample (ml)}} \times 100$$

Where 0.064* = acid milliequivalent factor.

3.3.7 Shelf Life of fruits

The fruits were kept at room temperature until they started to deteriorate. The number of days taken before rotting was observed on fruit was recorded as the shelf life.

3.4.0. Temperature and Relative Humidity of the storage area.

Temperature and relative humidity of the storage area was measured during the storage period using thermohyrometer.

Table 3.2 Temperature and Relative humidity recorded in the storage area

	Temperature(^o c)		Relative Humidity (%)	
	Minimum	Maximum	Minimum	Maximum
Mean	26.4	30.10	81.0	85.5

3.5.0 Assessment of consumer acceptability of tomato fruit that has been treated with different waxing materials

The study sought to measure consumers' acceptance of tomatoes coated with wax. A semi-structured questionnaire was used to collect data on consumer acceptability of tomato fruit treated with different waxing material and stored.

3.5.1. Sensory Analysis

Assessors were selected from the College of Agriculture and Consumer Sciences in the University of Ghana and asked to assess the visual quality of tomatoes that had been treated with different waxing material. Coded samples per treatment were assessed by each of the 10 member panel. A five-point Hedonic scale was used to score samples for skin colour, attractiveness, firmness, smell, and overall acceptability.

3.6.0 DATA ANALYSIS

The data collected on the laboratory experiments and sensory evaluation were subjected to analysis of variance (ANOVA) using computer software Genstat and the means were separated using LSD at 5%. The data collected on consumer acceptability and assessment of postharvest management practices with the questionnaire were analyzed using SPSS.

CHAPTER FOUR

4.0. RESULTS

4.1. INFORMATION ON FARMERS AND TRADERS IN THE STUDY AREA

4.1.1 General socio-economic characteristics of the study area

From a pre-interview interaction with opinion leaders and agriculture extension agents assigned to these communities, it was revealed that majority of the adult residents of these communities are crop farmers with most of them producing tomato. Some of the farming communities of the study area have important amenities such as good roads that facilitate transportation and electricity but others are typically rural with bad access roads and low level of development.

4. 1.2 Demographic information of respondents

4.1.2.1 Gender of respondents

Table 4. 1 Gender of respondents

Gender	Farmers		Traders	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Male	45.0	90.0	3.0	6.0
Female	5.0	10.0	47.0	94.0
Total	50.0	100.0	50.0	100.0

The study showed that tomato farming in the district is male dominated (90%) whiles trading of tomatoes is female dominated (94%).

4.1.2.2. Age characteristics of respondents

Table 4. 2 Age characteristics of respondents

Age (years)	Farmers		Traders	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Below 18	1.0	2.0	0.0	0.0
18 – 24	10.0	20.0	4.0	8.0
25 – 40	28.0	56.0	18.0	36.0
41 – 55	7.0	14.0	16.0	32.0
Above 55	4.0	8.0	12.0	24.0
Total	50.0	100.0	50.0	100.0

The study showed that the ages of farmers ranged between 18 and 60 years (Table 4.2). Farmers between the ages of 25-40 years were in the majority 38%. Farmers in the age range of 18-24 years were 20%, 41-55 years were 14%, above 55 years were 8% and one farmer representing 2% was below 18 years. On the other hand, the ages of traders ranged between 18 to 60 years. Traders between 25-40 years old were in the majority and accounted for 36%. Traders in the age range of 41-55 years were 32%, above 55 years were 24% and traders within the range of 18-24 years representing 8% were in the minority.

4.1.2.3 Educational level of respondents

Information gathered showed a generally low level of education among farmers in the districts (Table 4.3). Ten percent of farmers had secondary school education, 4% technical/vocational education, 8% middle school education, 16% primary school education, and 54% being the majority of farmers had up to JSS/JHS education and 8% of farmers had no education. None of the traders had education beyond the Junior high school level. A total of 42% of traders had

completed junior high school, 14% up to primary school education, 10% middle school education, 8% up to technical/vocational education and 26% had no formal education. Comparing the levels of education between farmers and traders, it was observed that the farmers had more JSS and secondary education than traders.

Table 4. 3 Educational level of respondents

Educational level	Farmers		Traders	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Primary	8.0	16.0	7.0	14.0
JHS/JSS	27.0	54.0	21.0	42.0
Middle School	4.0	8.0	5.0	10.0
Secondary	5.0	10.0	0.0	0
Technical/vocational	2.0	4.0	4.0	8.0
None	4.0	8.0	13.0	26.0
Total	50.0	100.0	50.0	100.0

4.1.2.4 Years of experience in tomato business

The study showed that 38% of farmers had between 6 – 10 years of experience in tomato farming, 36% between 6 – 10 years of experience, 18% between 10 -15 years of experience and 8% had above 16 years of experience in tomato farming. On the other hand, 32% of traders had below 6 years of experience, 24% between 6 - 10 years of experience, and 44% of them had 10 - 15 years of experience in tomato trading (Table 4.4).

Table 4. 4 Years of experience in tomato business

Experience (years)	Farmers		Traders	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Below 6	19.0	38.0	16.0	32.0
6 - 10	18.0	36.0	12.0	24.0
10 – 15	9.0	18.0	22.0	44.0
Above 16	4.0	8.0	0.0	0.0
Total	50.0	100.0	50.0	100.0

4.1.2.5 Tomato varieties cultivated and sold by respondents**Table 4. 5 Tomato varieties cultivated and sold by respondents**

Varieties	Farmers		Traders	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Pectomech	19.0	38.0	18.0	36.0
Ada lorry tyre	6.0	12.0	5.0	10.0
'No Name'	2.0	4.0	3.0	6.0
Others (66)	4.0	8.0	1.0	2.0
Total	50.0	100.0	50.0	100.0

The major tomato varieties grown in the study area included Power Rano (popularly referred to as local) and Akoma (suspected to be a Pectomech). However from observation, almost all the

farmers cultivated more than one variety. It can be seen from Table 4.5 that 38% of farmers cultivate Power (local), 36% cultivate Pectomech, 12% cultivate Ada lorry tyre, and 8% cultivate Six-six (66) and 4% cultivate 'No Name'. The survey also showed that all traders sold more than one variety of tomato. Pectomech and Power Rano were the predominant varieties sold by traders. Forty- six percent of traders sell Power (local), 36% sell Pectomech, 10% Ada lorry tyre, 6% 'No Name', and 2% sell six-six (66).

4.1.2.6. Description of farming activity by farm size.

Farm size ranged from half an acre to twenty five acres which have been grouped into small scale (> 1 acre – 10 acres), medium scale (11 acres – 20 acres) and large scale (above 20 acres). When a farmer had more than one farm, the acreage of all farms was added to arrive at the data analyzed. By this grouping, 72% of farmers do small scale farming, 22% medium scale farming and 6% do large scale farming.

Table 4. 6 Description of farming activity by farm size

Farm activity	Farm size (Acres)	Frequency	Percent (%)
Small Scale	1-10	36.0	72.0
Medium Scale	11- 20	11.0	22.0
Large Scale	21-25	3.0	6.0
Total		50.0	100.0

4.1.2.7. Source of planting material for farmers

Table 4. 7 Source of planting materials for farmers

Source of planting materials	Frequency	Percentage (%)
Family	3	6.0
Friends	20	40.0
MOFA	7	14.0
Others (agro-chemical stores)	20	40.0
Total	50	100.0

The study shows that 40% of farmers obtain their planting materials from friends and other agro-chemical stores, 14% from the Ministry of Food and Agriculture (MOFA) while 6% of farmers obtain their planting materials from family members.

4.1.3.0. POSTHARVEST MANAGEMENT PRACTICES ALONG THE TOMATO VALUE CHAIN IN FANTEAKWA DISTRICT

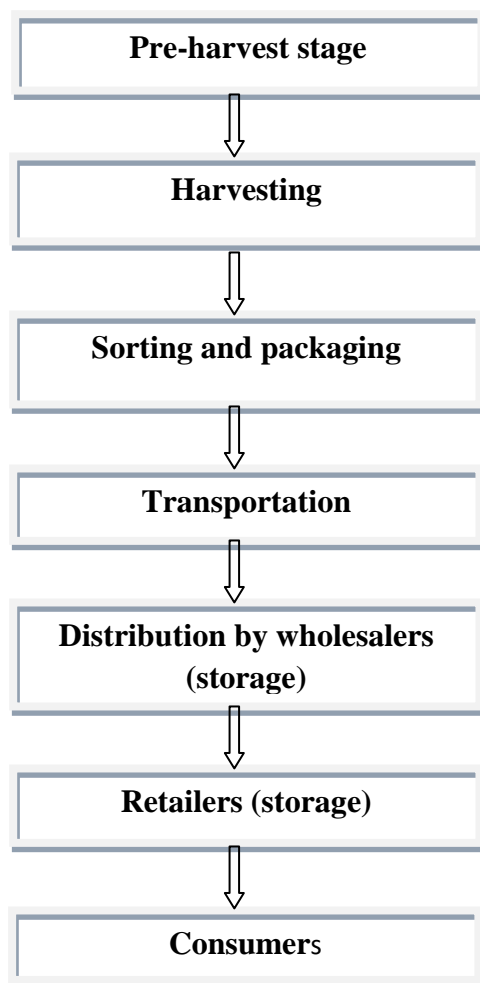


Figure 4. 1 A flow chart showing the tomato value chain in Fantekwa District

4.1.3.1. Pre-harvest stage

The study revealed that the tomato value chain started from pre-harvesting stage which involved land preparation, nursing of seed and transplanting of seedlings into the field. Maintenance activities such as weed control, insect pest control and disease control were carried out at regular intervals until fruits were harvested at a physiologically matured stage.

4.1.3.2 Harvesting practices

Time of Harvesting differed among farmers in the study area. Seventy-six percent of farmers harvested their fruit in the morning, 18% harvested at no specific time and 6% harvested in the afternoon. Majority of farmers who harvested their fruit in the morning indicated that they do so to prevent excessive heat and to prolong the shelf life. Farmers in the districts mostly harvested in the morning which happened to be the time traders normally arrived. Almost every farmer knew that it is best to harvest tomatoes in the morning and was aware of the postharvest implication of the time of harvest on the produce. Majority of farmers (92%) harvested fruits when they are fully ripened while 8% harvested half ripe fruits. All farmers interviewed harvested their produce manually by hand twisting to break off the stalk. Harvesting was done manually either directly into boxes (bins) or first into buckets and emptied into the boxes. Some farmers used hired labour to harvest their produce and their wages depended on the quantity of tomatoes harvested per day. It was observed on some of the farms visited, that harvested produce were poured from buckets at head height into bins due to the competition among the harvesting groups. It was observed that harvested produce were left in the hot sun until harvesting was over. About 98% of farmers incurred losses during harvesting while 2% of farmers did not incur losses during harvesting. It was also observed that some farmers put harvested produce into any available container and left them by the roadside hoping to either get buyers from among travelers or

transport to the market (Plate 4.1). The produce could be left in the sun for many days before being sold. This was more prevalent in some of the communities located along the main road.



Plate 4. 1 Tomato lined up along the roadside awaiting prospective buyers or transport.

4.1.3.2.1. Type of losses incurred during harvesting

The results showed that of the 50 respondents, 14% indicated rotting was the major type of loss during harvesting, 36% and 50% mentioned physiological and mechanical damage as the major type of losses during harvesting of fruits, respectively (Table 4.8).

Table 4. 8 Type of losses incurred during harvesting

Type of losses	Frequency	Percentage
Physiological	18	36.0
Rotting	7	14.0
Mechanical	25	50.0
Total	50	100.0

4.1.3.2.2. Quantity of losses suffered during harvesting

The quantity of losses incurred during harvesting ranged from one box to 6 boxes of fruits. Eighty percent of farmers incurred fruit losses of 1 - 2 boxes, 16 % from 3- 4 boxes and 4% incurred losses of 5- 6 boxes. However it was observed that the quantity of fruits that got damaged on most farms was higher than those sold.

Table 4. 9 Quantity of losses suffered during harvesting

Quantity of Fruit losses (Boxes)	Frequency	Percentage (%)
1 -2	40	80.0
3-4	8	16.0
5- 6	2	4.0
Total	50	100.0

4.1.3.3. Sorting and package practices.

It was observed that all farmers did not practice any form of pre-cooling before packing produce into bins. Farmers in the study area sorted fruits into sizes before packing them for the market (plate 4.2). The results of the present study showed that 16% of the respondents packed fruits in shallow wooden boxes, 66% in long big wooden boxes, and 2% in plastic baskets, while 16% in

cane basket. These packaging materials were reported to be cheap and mostly available (Plate 4.3).

Table 4. 10 Types of Packaging materials

Packaging materials	Frequency	Percentages (%)
Shallow wooden boxes	8.0	16.0
Long Big Wooden boxes	33.0	66.0
Plastic Basket	1.0	2.0
Cane Basket	8.0	16.0
Total	50.0	100.0



Plate 4. 2 A farmer sorting out tomatoes for sale along the roadside



Plate 4. 3 Some packaging practices by respondents (Sorting & placing)

4.1.3.3.1. Type of losses incur during packaging

About 82% of respondents incurred losses during packaging while 18% of the respondents do not. The results revealed that of 50 respondents, 82% indicated that mechanical damage was the major type of loss during packaging while 12% and 6% mentioned rotting and physiological damage as the major type of losses during packaging of fruits, respectively.

Table 4.11 Types of losses incurred during packaging

Type of losses	Frequency	Percentage (%)
Mechanical	41	82.0
Rotting	6	12.0
Physiological	3	6.0
Total	50	100.0

4.1.3.3.2. Quantity of losses suffered during packaging.

The quantity of fruit losses incurred during packaging ranged from a box to 6 boxes. Ninety percent of farmers incurred losses from 1 - 2 boxes, 6% from 3- 4 boxes and 4% incurred losses of 5-6 boxes during packaging.

Table 4. 12 Quantity of losses suffered during packaging

Quantity of losses (boxes)	Frequency	Percentage (%)
1-2	45	90.0
2-4	3	6.0
5-6	2	4.0
Total	50	100.0

4.1.3.4. Storage practices

The results revealed that all the farmers were unable to (do not) store their produce when there was no ready market but rather left the fruits on the farm to rot. However, they were willing to adopt innovative storage methods to extend the shelf life of their produce. On the other hand, 88% of traders were unable to prolong the shelf life of their produce and 12% of the traders were able to prolong the shelf life their produce. The traders responded that they were usually unable to store their produce to prevent or reduce spoilage. When there was no ready market traders preserved their produce by keeping the fruits on bare cemented or wooden floor (Plates 4.4). About 94% of traders experienced losses through spoilage while 6% experienced nominal loss of their produce through spoilage. Regarding the rate of tomato spoilage in the study area, 62% of traders indicated that it was very high, 30% as high, 6% as low and 2% of the traders responded that it was very low.



Plate 4. 4 Some methods of storage of tomato fruits by traders

4.1.3.4.1. Type of losses incurred during storage.

The results revealed that 80% of traders indicated that rotting is the major type of loss during storage, 16% and 4% mentioned mechanical and physiological damage as the major type of losses during storage of fruits, respectively.

Table 4. 13 Type of losses incurred during storage

Type of losses during storage.	Frequency	Percent (%)
Rotting	40.0	80.0
Mechanical	8.0	16.0
Physiology	2.0	4.0
Total	50.0	100.0

4.1.3.4.2. Quantity of losses suffered during storage.

The quantity of fruit losses incurred during storage ranged from a box to 8 boxes. Fifty-two percent of traders incurred losses of up to 3 - 4 boxes, 28% of up to 1- 2 boxes, and 12% of them also incurred losses of up to 5-6 boxes and 7-8 boxes during storage.

Table 4. 14 Quantity of losses suffered during storage

Quantity of losses suffered during storage (Boxes)	Frequency	Percentage (%)
1 - 2	14.0	28.0
3 - 4	26.0	52.0
5 - 6	6.0	12.0
7 - 8	6.0	12.0
Total	50.0	100.0

4.1.3.5. Transportation.

The study showed that the mode of transportation of purchased produce from the farm gate to the point of sale was by vehicles and by head-loaded porters. About 92% of respondents usually transported their purchased produce from the farm gate to the point of sale by vehicle whilst 8% of respondents conveyed their produce by head-loaded porters. About 42% of respondent used open trucks in transporting their produce, 34% used van or roofed truck and 24% used taxi as medium of transport (plate 4.5). In rating the condition of vehicles used in transporting tomato produce in the study area, 34% of respondents said it was very good, 22% indicated that it was very bad, 4% responded that it was bad while 20% indicated that it was both good and average. In assessing the condition of the road network in the study area, 34% indicated that it was very

good, 20% responded that it was good, 22% indicated that it was very bad, 4% said it was bad while 20% indicated that it was average (Plate 4.6)



Plate 4. 5 Type of vehicles used in transporting tomato produce



Plate 4. 6 Some of roads on which tomato produce are transported

4.1.3.5.1. Type of losses suffered during transportation.

About 88% of the respondents incurred losses during transportation while 12% of the respondents did not. The results showed that 84%, 2% and 2% of the major type of loss during transportation declared by respondents was mechanical damage, rotting and physiological damage, respectively.

Table 4. 15 Type of losses suffered during transportation

Losses suffered during transportation	Frequency	Percentage (%)
Mechanical	42.0	84.0
Rotting	1.0	2.0
Physiological	1.0	2.0
Total	44.0	100.0

4.1.3.5.2. Quantity of losses sustained during transportation.

Quantity of losses incurred during transportation ranged from a box to 8 boxes. Thirty percent of traders incurred losses of up to 3 - 4 boxes, 44% up to 1 - 2 boxes and 20% of up to 5 - 6 boxes. Six percent of traders incurred losses of up to 7- 8 boxes during transportation.

Table 4. 16 Quantity of losses incur during transportation

Quantity of losses (Boxes)	Frequency	Percentage (%)
1-2	22.0	44.0
3-4	15.0	30.0
5-6	10.0	10.0
7-8	3.0	6.0
Total	50.0	100.0

4.1.4.0. POST-HARVEST LOSSES AND PRACTICES.

4.1.4.1. Practices that affect postharvest quality.

About 80% of farmers said most of the practices that affected postharvest quality were fertilizer and pesticides application. Ten percent, 6% and 4% indicated that land preparation, weeding and thinning, respectively affect postharvest quality of tomato fruit.

4.1.4.2. Causes of postharvest losses of tomatoes from farmers' and traders viewpoint.

The various causes of postharvest losses in the study area were identified and almost all farmers attributed losses to a number of factors (Table 4.16). About 34% of farmers interviewed attributed the greatest of pre-harvest and postharvest losses of their produce to lack of market, 32% attributed it to lack of storage technology, 20% attributed it to lack of storage facility, 8% indicated that lack of transport for harvested produce accounted for losses, 4% attributed it to pest and disease and 2% to lack of processing plant. On the other hand, it was observed through this study that traders had ever experienced losses of their produce and most of the losses were recurrent. Generally, 54% of traders attributed losses to lack of storage technology, 34% to lack of market, 4% to lack of transport for produce, 4% to lack of storage facility and 2% to pest attack and disease (Table 4.17).

Table 4. 17 Factors that accounts for postharvest losses of tomatoes

Causes of Postharvest losses	Farmers		Traders	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Lack of market	17.0	34.0	17.0	34.0
Lack of transport for produce	4.0	8.0	2.0	4.0
Lack of storage facility	10.0	20.0	2.0	4.0
Lack of storage technology	16.0	32.0	27.0	54.0
Pest attack and disease	2.0	4.0	1.0	2.0
Lack of processing plants	1.0	2.0	0.0	0.0
Total	50.0	100.0	50	100.0

4.1.4.2. Causes of postharvest losses of tomatoes from farmers' and traders viewpoint.

4.1.5.0. Type of losses along the tomato postharvest value chain.

The type of losses along the tomato postharvest value chain included mechanical, rotting and physiological losses (Figure 4.1). During harvesting the losses that occurred were mechanical losses (50%), rotting (14%) and physiological loss (36%). In sorting and packaging, the losses that occurred include mechanical losses (82%), rotting (12%) and physiological losses (6%). In storage, 80% of respondent indicated rotting as the cause of loss, 16% mechanical losses and 4% physiological losses. In transportation, 84% mentioned mechanical losses, 2% mentioned rotting and physiological loss as the major losses that occurred during transportation.

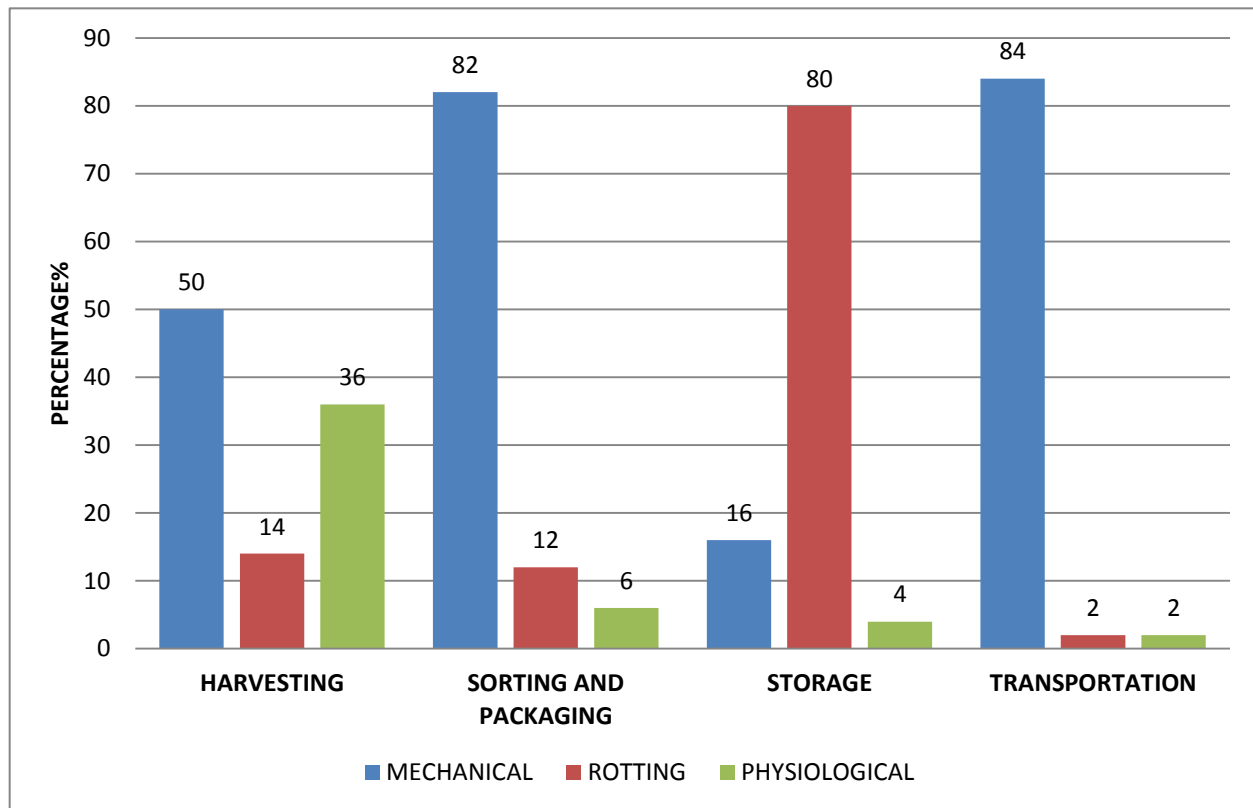


Figure 4.1.1 Type of losses along the tomato postharvest value chain

4.1.6.0. Farmers and Traders Perception on waxing of tomato fruit.

The study revealed that 92% of traders and all the farmers had no knowledge of any effective storage technology for tomato fruits while 8% of traders had knowledge on how to store their tomatoes. All farmers and traders did not wax fruits before preservation. The study also showed that 94% of farmers and 86% of traders were willing to accept new methods of preserving of tomato fruit if it is more effective while 6% and 14% of farmers and traders respectively were not willing to accept any new method of preserving of tomatoes.

4.2.0. Effect of waxing on the quality changes of tomato fruit that has been treated with different waxing materials.

Several changes in physical and chemical characteristics of tomatoes were observed following the different waxing treatments over a period of time.

4.2.1. Percentage Weight Loss (% WL) following different waxing treatment.

The percentage weight loss of the two tomato varieties increased with the storage period and was higher for the control fruits in the two varieties than the treated fruits from day 5 to day 20 (Figure 4.2.1.). However, the control for the two varieties had a shelf life of ten days. The maximum weight loss (29.49%) from day 5 to 10 for the Pectomech variety was recorded for the control and this figure was statistically different ($p>0.05$) from the weight loss of the other treatments and their combinations. The minimum weight loss (5.55%) was recorded with BW treatment. There was a significant decrease in % WL due to waxing and varietal effect. BW treatment was statistically different ($p>0.05$) from SB and CS (Appendix 1.1). However, there was significant effect of waxing/variety interactions on % WL. Comparing fruits treated with SBCS, SBBW and BWCS, those with SBCS recorded the highest weight loss (8.68%), followed by SBBW (5.76%) then BWCS (5.71%). The difference in % weight loss between the two (BWCS and SBBW) was statistically different from SBCS. Interestingly, from day 15 - day 20, there was also a significant decrease in % WL in waxing and variety effect. The highest weight loss (38.7%) was recorded with CS coated fruits whilst BW coated fruits recorded the lowest (24.35%). However BW, CS and SB coated fruits were the same statistically (Appendix 1.1). On the other hand, there was also significant effect of waxing/variety interactions on % WL. SBCS recorded the highest weight loss (38.5%) while SBBW recorded the lowest weight loss (27.9%).

In all, BW and its combination reduced weight loss than the other treatments and their combinations (Figure 4.2.1).

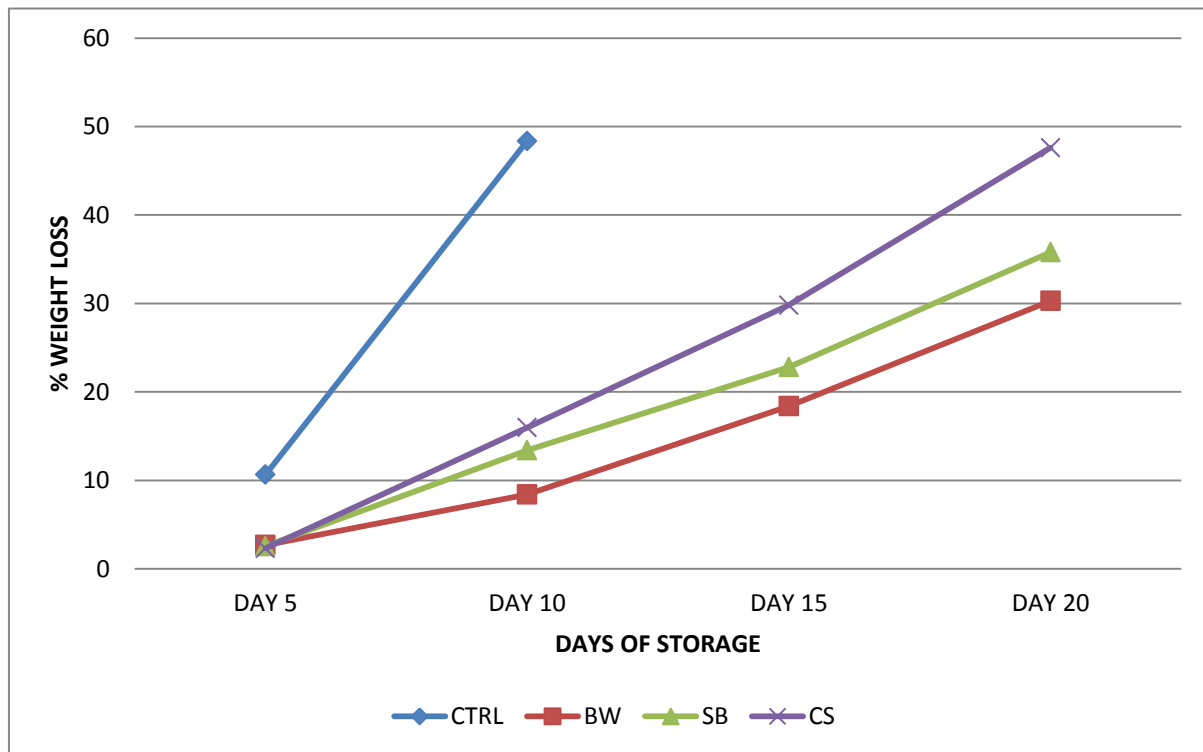


Figure 4.2. 1a Changes in %WL following different waxing treatment on Pectomech

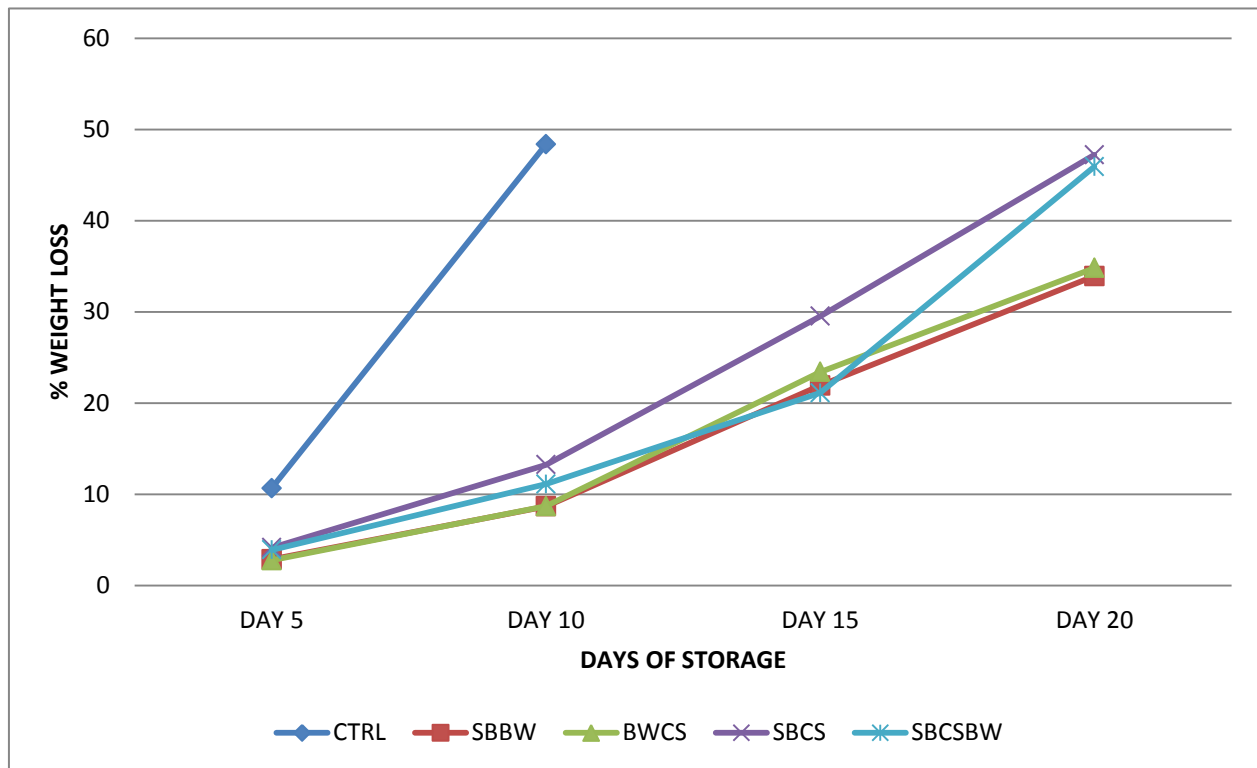


Figure 4.2. 1b Changes in %WL following different waxing treatment on Pectomech

For the Power variety, the maximum weight loss (45.34%) from day 5 to 10 was recorded for the control fruits and the figure was statistically different ($p > 0.05$) from the other treatments and their combinations. The minimum weight loss (5.91%) was recorded with the BW treatment. There was a significant loss in %WL due to waxing effect. BW treatment was significantly different in weight loss ($p > 0.05$) from SB and CS. However, there was a significant effect of waxing/varieties interactions on the % WL. SBCS recorded the maximum weight loss (9.92%) while SBBW recorded the minimum weight loss (6.23%). The % WL in SBBW was not significantly different ($p > 0.05$) from BWCS. However, from day 15 to 20, the results show that there was a significant increase in percentage weight loss in waxing and variety. The maximum weight loss (52.59%) was recorded with the CS treatment. BW treatment showed the minimum weight loss (26.5%). There was significant difference between the interactions

(Appendix 1.2).BW treatment and its combinations reduced weight loss than the other treatments (Figure.4.2.2). In all, the percentage weight loss in fruits was higher in Power than the Pectomech.

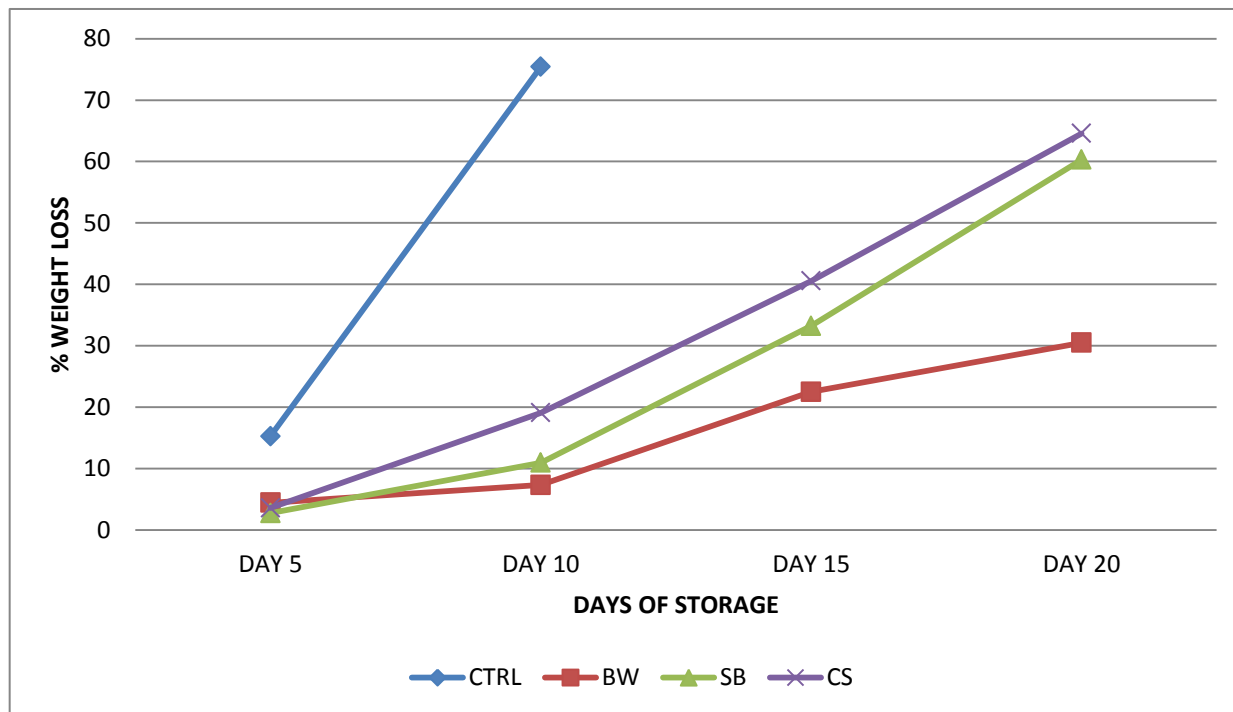


Figure 4.2. 2a Changes in %WL following different waxing treatment on Power

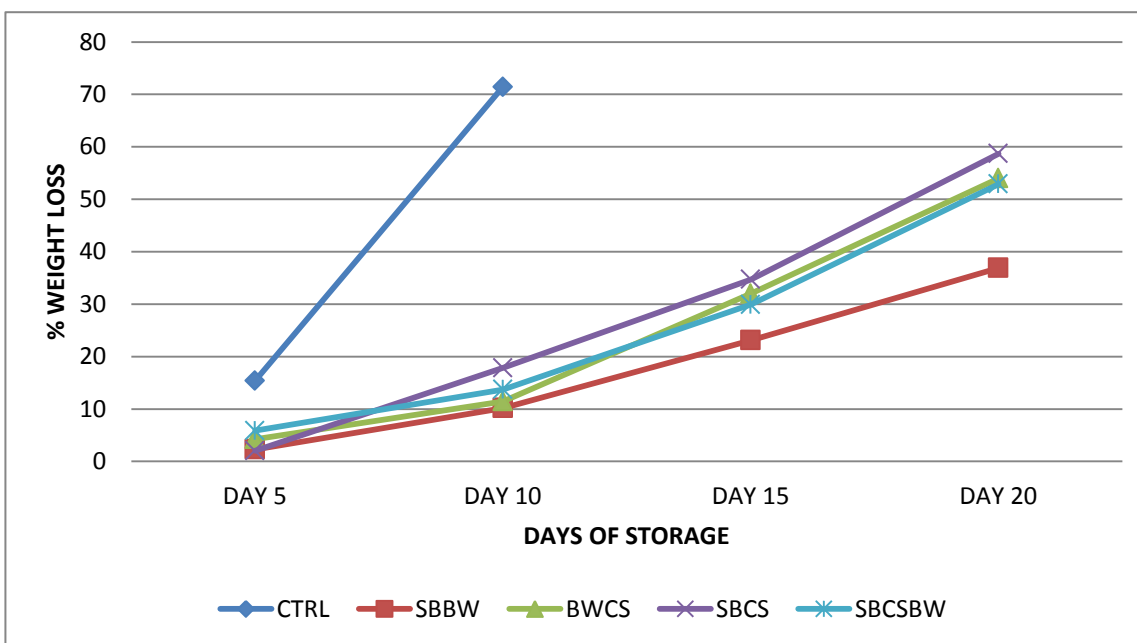


Figure 4.2. 2b Changes in %WL following different waxing treatment on Power

4.2.2. Firmness of tomato varieties following different waxing treatment.

The study showed that there was a significant decrease in firmness from day 0 to 20 and the control fruits were softer than than the treated fruits. There was significant difference ($p < 0.05$) with waxed fruits and between varieties as well as their interactions. The control for both varieties had a shelf life of ten days.

Pectomech fruits in the control treatment recorded the lowest value (2.52) for firmness from day 0 to 10 and it was significantly different ($p < 0.05$) from the other treatments and their combinations. The SBBW coated fruits recorded the highest value (3.89) for firmness however this was not significantly different ($p < 0.05$) from the other treatment and their combinations. However, from day 15 to 20, SBBW treatment recorded the highest firmness (2.37) which was not significantly different ($p < 0.05$) from BW (2.29), BWCS (2.03) and SB (1.83) coated fruits. Fruits coated with CS recorded the lowest firmness (1.28) and was significantly different ($p < 0.05$) from the other treatments and their combinations. The firmness values for fruits coated with SBCS and SBCSBW were similar statistically (Table 4.2.1). The changes in firmness of pectomech fruits that occurred after 20 days of storage following the different waxing treatment are shown in the Table 4.2.1

Table 4.2. 1 EFFECT OF DIFFERENT WAXING MATERIAL ON THE FIRMNESS OF PECTOMECH TOMATO

	DAY 0	DAY 5	DAY 10	MEANS	DAY 15	DAY 20	MEANS
BW	4.27	3.70	3.00	3.68a	2.50	2.07	2.29a
BWCS	4.27	3.56	3.02	3.61a	2.25	1.81	2.03a
CS	4.67	2.67	2.00	3.11a	1.50	1.07	1.28c
CTRL	4.37	2.17	1.03	2.52b			
SB	4.44	3.17	2.57	3.39a	2.08	1.57	1.83a
SBBW	4.43	3.93	3.30	3.89a	2.65	2.08	2.37a
SBCS	4.33	2.75	2.23	3.11a	1.52	1.07	1.30b
SBCSBW	4.07	3.00	2.53	3.20a	2.04	1.37	1.70b
F pr. (0.05)	0.53	<0.01	<0.01		0.006	0.016	

All means sharing similar letters are statistically non-significant at 0.05 probability level.

For Power , the lowest firmness from day 0 to 10 was recorded with the control fruits (1.97) and was significantly different ($p < 0.05$) from the other treatments and their combinations. The highest firmness was recorded with BW treatment(3.57) which was not significantly different ($p < 0.05$) from the other treatments except SBCS and the control. A similar trend was observed from day 15 to 20. SBCS treatment recorded the lowest firmness (1.06) and was significantly different ($p < 0.05$) from the other treatments and their combinations. A significant highest fruits firmness was recorded with BW treatment (2.32) as compared to the other treatments except SBCS treatment. The changes in firmness of Pectomech fruits that occurred after 20 days of storage following the different waxing treatment are shown in (Table 4.2.2).

Table 4.2. 2 EFFECT OF DIFFERENT WAXING MATERIAL ON THE FIRMNESS OF POWER TOMATO

	DAY 0	DAY 5	DAY 10	MEANS	DAY 15	DAY 20	MEANS
BW	4.02	3.52	3.17	3.57a	2.57	2.07	2.32a
BWCS	3.97	3.20	2.40	3.19a	1.74	1.42	1.58a
CS	3.93	2.42	1.93	2.76a	1.27	0.91	1.09a
CTRL	3.77	1.40	0.73	1.97c			
SB	3.87	3.01	2.4	3.09a	1.80	1.33	1.57a
SBBW	4.07	3.52	2.75	3.45a	2.13	1.73	1.93a
SBCS	3.90	2.50	1.67	2.69b	1.18	0.93	1.06b
SBCSBW	4.03	2.93	2.00	2.99a	1.53	1.20	1.37a
F pr.(0.05)	0.53	<0.01	<0.01		0.006	0.016	

All means sharing same letters are statistically non-significant at 0.05 probability level.

4.2.3. Total Soluble Solids (TSS) or % Brix on tomato varieties following different Waxing treatment.

The changes that occurred in Total Soluble Solids (TSS) showed that, there was a significant increase in TSS from day 0 to day 10 and a gradual decline from day 10 to day 20 for both tomato varieties studied. (Figure 4.2.3 - 4.2.4).

For Pectomech, there was a significant difference in waxing and varietal effect as well as the interaction from day 0 to 10. The control fruit had maximum TSS (4.49) which was statistically different ($p > 0.05$) from fruits of the other treatments and their combinations. BW treatment fruits had the lowest TSS (3.1) which was statistically different ($p < 0.05$) from those of SB (3.62) and CS (3.8) treatments. There was a significant effect of waxing/variety interaction on TSS. SBCS fruits had the highest TSS (3.55) while SBBW fruits recorded the lowest TSS (3.17). The TSS from day 15 to 20 showed a gradual decline (Figure 4.2.3). SBCS recorded the highest TSS (4.87) which was significantly different ($p < 0.05$) from the other treatments and their combinations. BW treatment fruits showed the lowest TSS (4.1) which was significantly different ($p < 0.05$) from fruits of SB (4.45) and CS (4.73). There was a significant difference in the interaction but TSS in BWCS was not statistically different from SBCSBW.

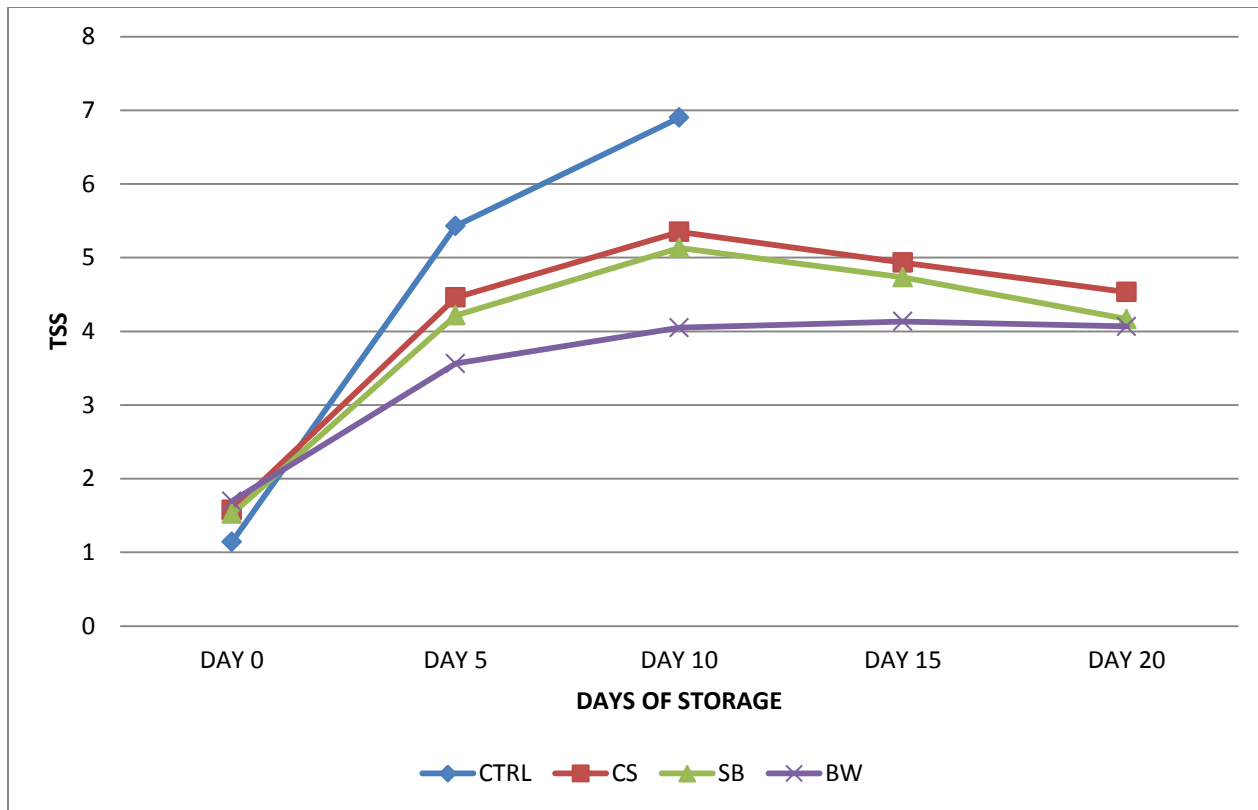


Figure 4.2. 3a Changes in TSS of Pectomech following different waxing treatments

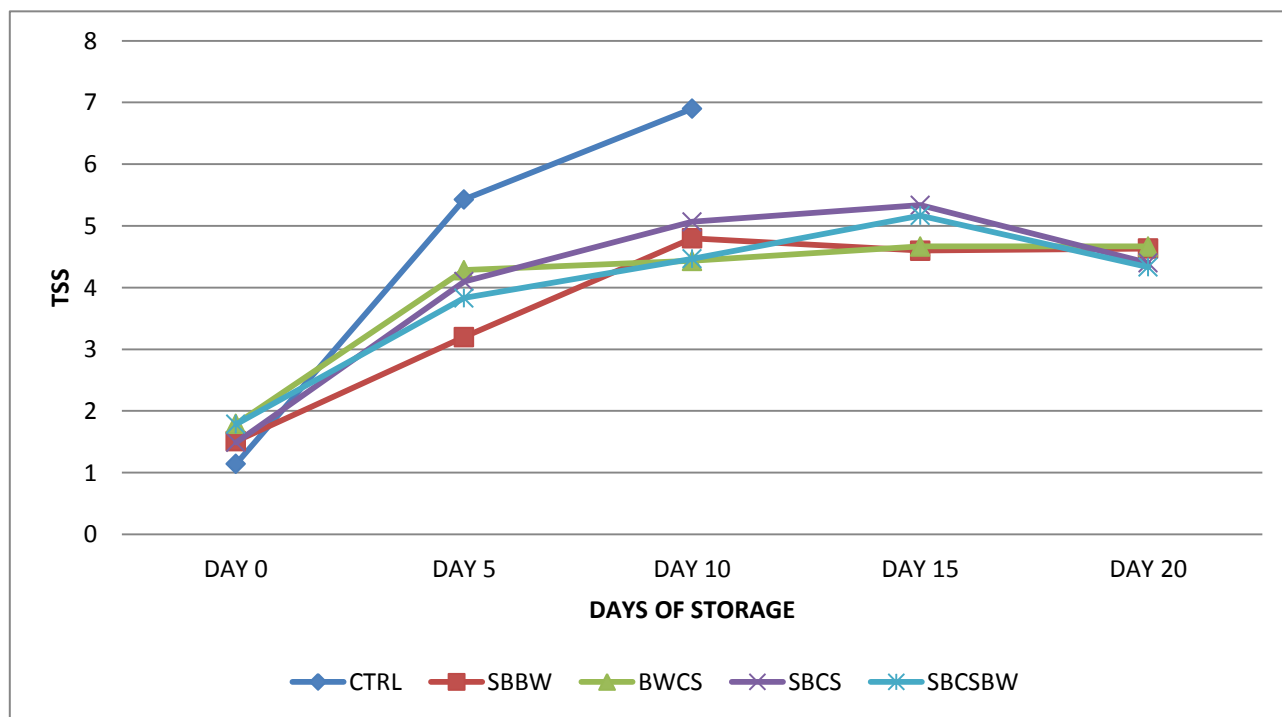


Figure 4.2. 3b Changes in TSS of Pectomech following different waxing treatments

For Power, there was a significant increase in TSS from day 0 to day 10 and a gradual decline from day 10 to day 20 (Figure 4.2.4). However from day 0 to day 10, the control treatment retained the highest TSS (5.08) which was statistically different ($p>0.05$) from the other treatment and their combinations. BW treatment showed the lowest TSS (3.7) which was statistically different ($p<0.05$) from the other treatment and their combinations. There was significant effect of waxing/variety interaction on TSS. However, BWCS was not significantly different ($p<0.05$) from SBCS and SBCSBW (Appendix 1.4). On the other hand, from day 15 to 20, there was a gradual decline in TSS. CS treatment recorded the highest TSS (5.65) which was significantly different ($p>0.05$) from the other treatment and their combinations. BW treatment showed the lowest TSS (4.67). There was a significant effect of waxing/variety interaction on TSS.

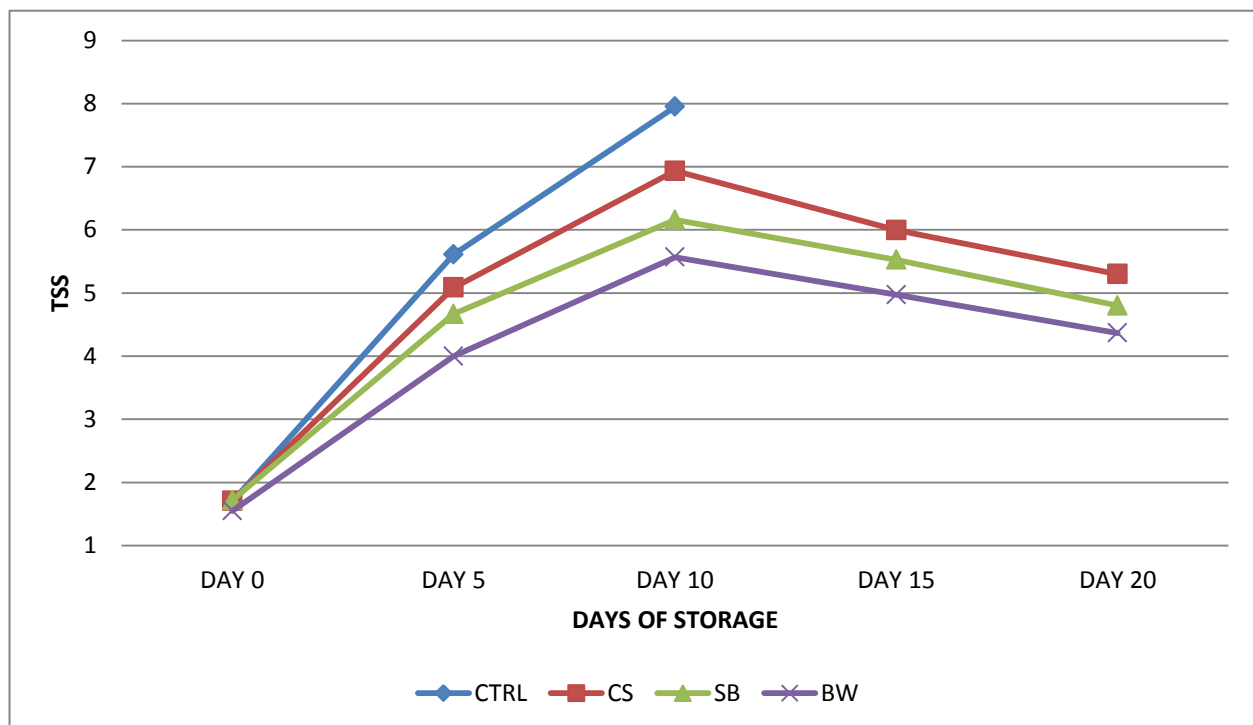


Figure 4.2. 4a Changes in TSS of Power following different waxing treatment

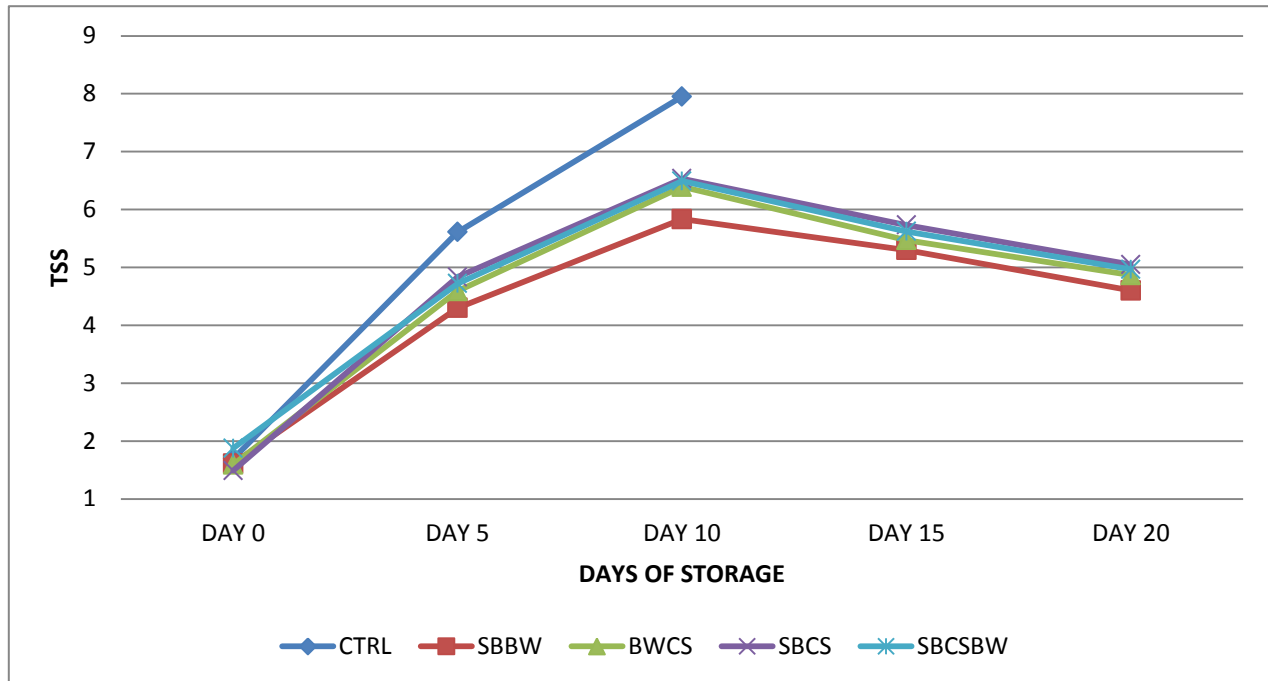


Figure 4.2. 4b Changes in TSS of Power following different waxing treatment

4.2.4. TTA of tomato varieties following different Waxing treatment.

The study showed that there was a significant ($p < 0.05$) decrease in TTA from day 0 to 20 as well as a significant difference in waxing and variety effect and their interactions.

For Pectomech, there was a significant difference in TTA due to waxing and varietal effect as well as the interactions from day 0 to day 10. BW treatment recorded the highest TTA (0.79) and was significantly different ($p < 0.05$) from the other treatment and their combinations. The control fruits recorded the lowest TTA (0.55). However, BW treatment was not significantly different ($p < 0.05$) from BWCS, SBBW and SB. A similar trend was also observed from day 15 to day 20. The highest TTA (0.55) was recorded with the BW treatment with CS treatment having the lowest TTA (0.36). The BW treatment was significantly differently ($p < 0.05$) from the other treatment and their combinations but there was no significant differences between BWCS and SBBW (Appendix 1.5).

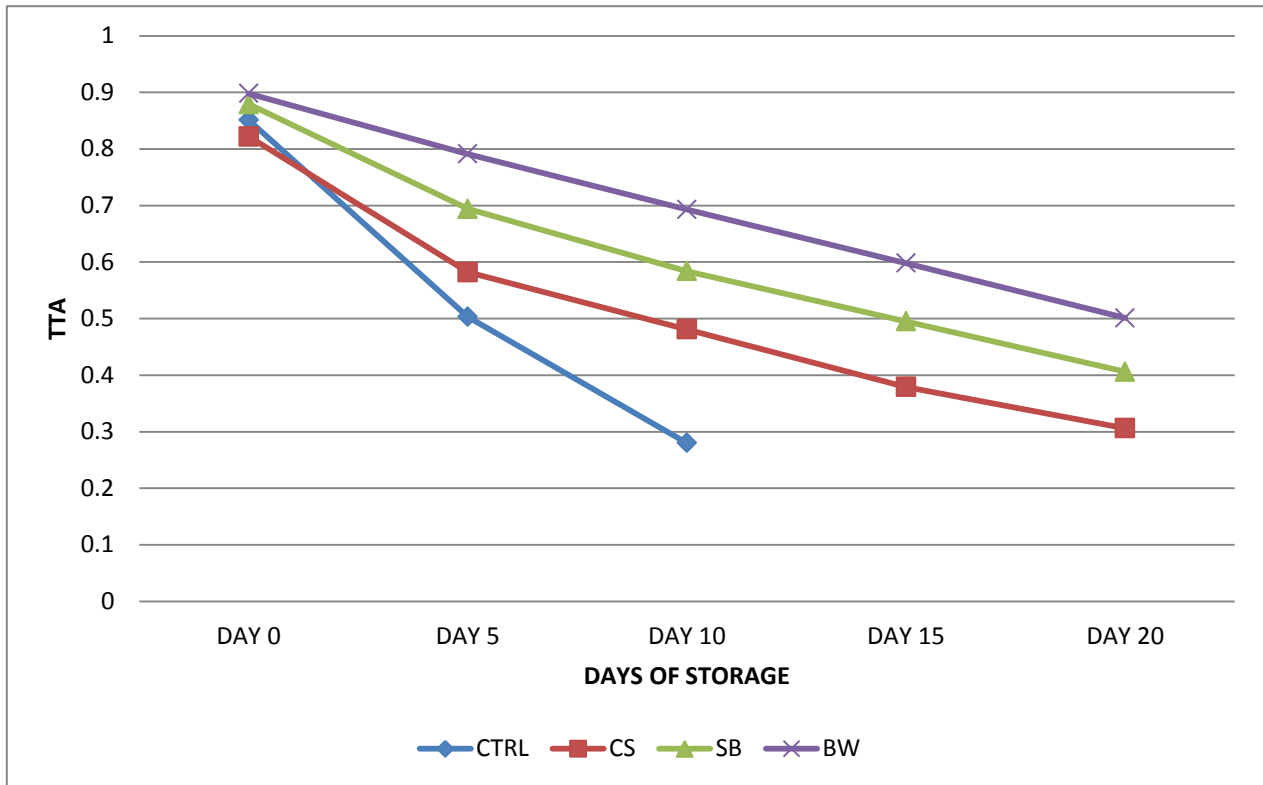


Figure 4.2. 5a Changes in TTA of Pectomech following different waxing treatment

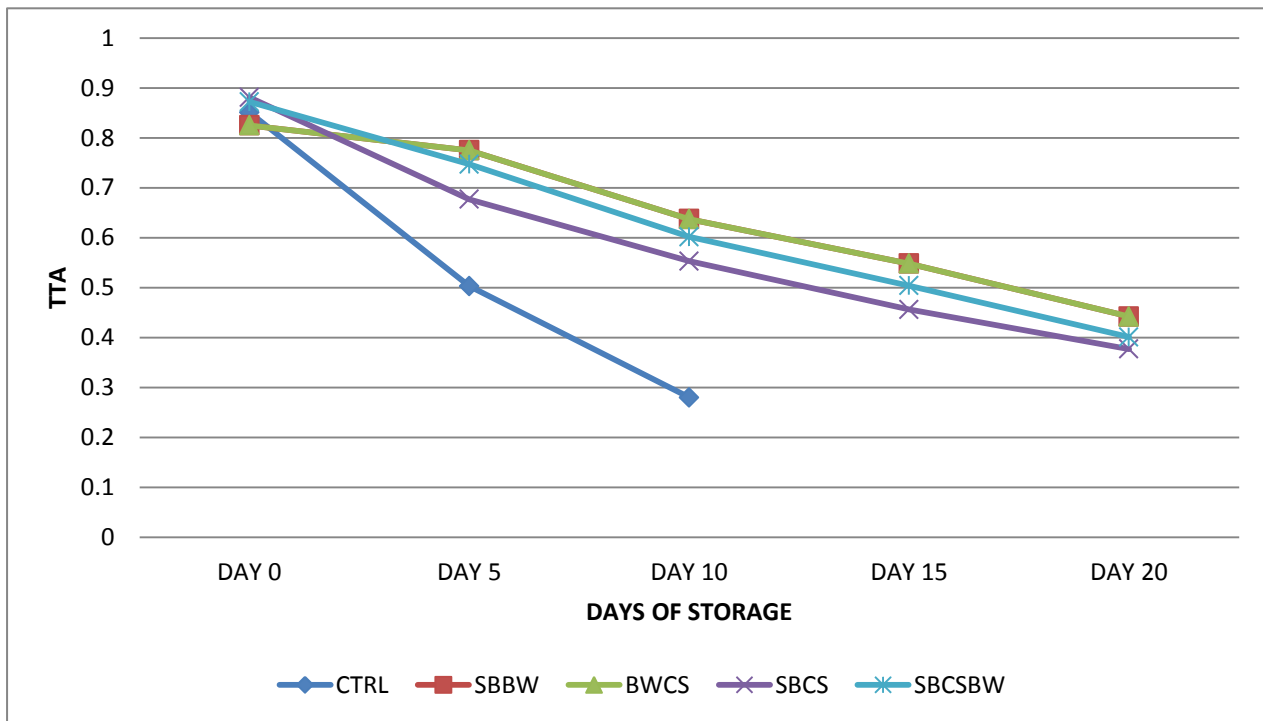


Figure 4.2. 5b Changes in TTA of Pectomech following different waxing treatment

For Power, there was a significant difference in TTA following waxing and variety effect as well as their interactions. A similar trend was also observed from day 0 to 10 and there was a gradual decline in TTA as well (Figure 4.2.8). BW treatment recorded the highest TTA (0.80) while the control fruits recorded the lowest TTA (0.52). BW treatment was not significantly different ($p < 0.05$) from BWCS, SBBW, SB, CS and SBCSBW. However, from day 15 to 20, there was also a significant difference ($p > 0.05$) in TTA due to waxing and variety effect as well as the interactions. BW treatment recorded the highest TTA (0.54) and it was significantly different ($p > 0.05$) from the other treatment and their combinations. CS treatment recorded the lowest TTA (0.31).

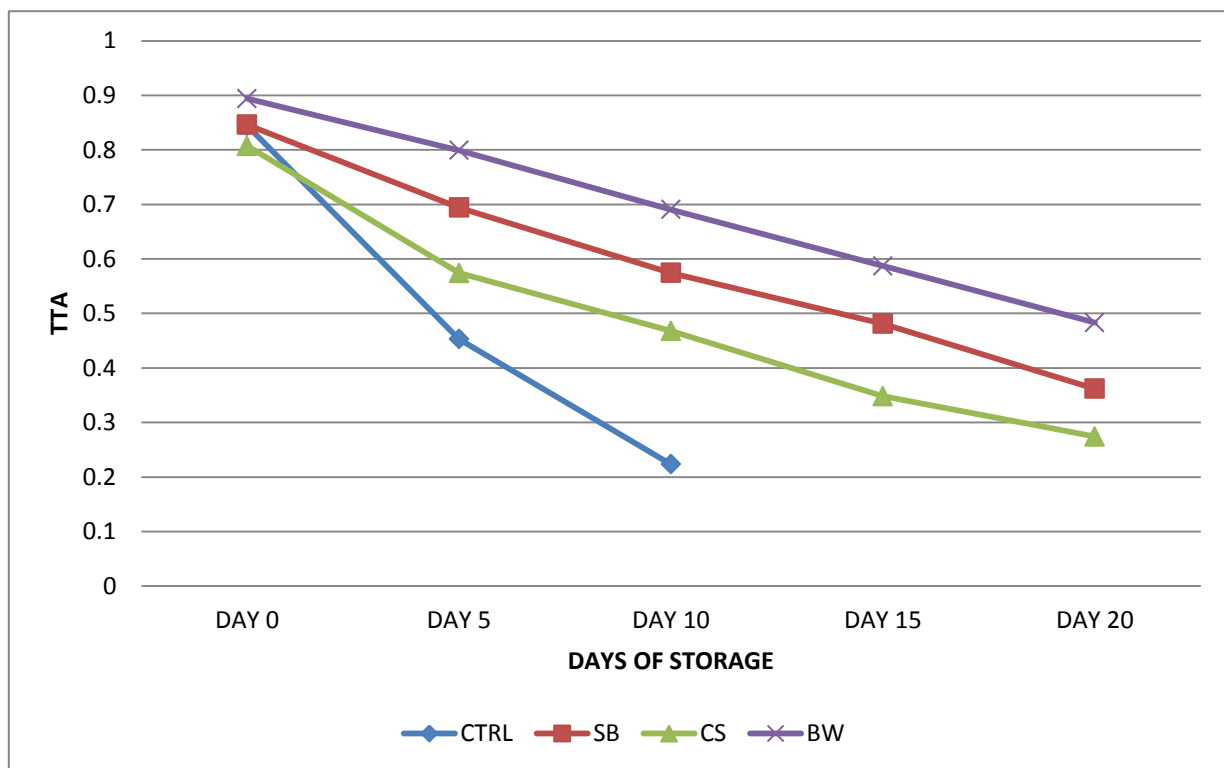


Figure 4.2. 6a Changes in TTA of Power following different waxing treatments

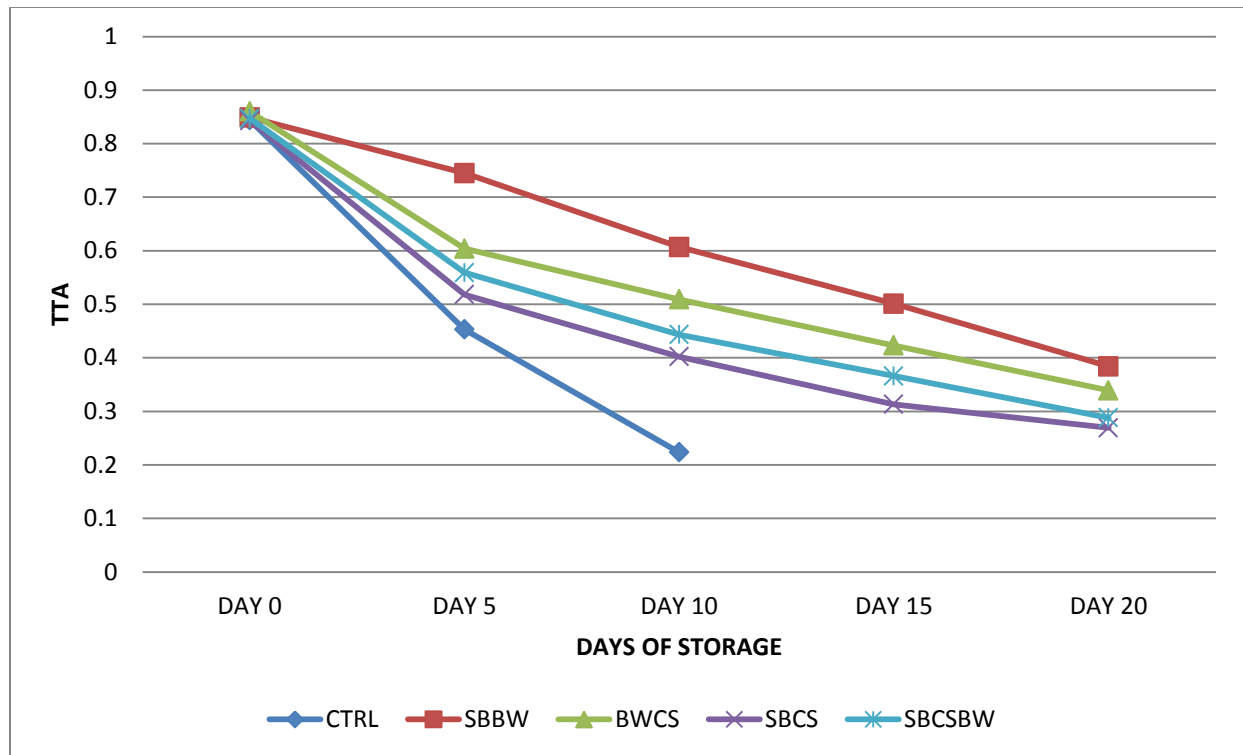


Figure 4.2. 6b Changes in TTA of Power following different waxing treatments

4.2.5. pH of tomato varieties following different waxing treatments.

It was noted that, there was a significant ($p < 0.05$) increase in pH from day 0 to 20. For Pectomech, it was noted that there was a significant difference in pH following waxing and varietal effect as well as their interaction from day 0 to 10. The control treatment recorded the highest pH (3.95) and was not statistically different ($p < 0.05$) from other treatments and their combinations except BW and SBBW treatments. However, BW treatment recorded the lowest pH (2.6) and it was not statistically different ($p > 0.05$) from SBBW treatments (Appendix 1.7). A similar trend was observed from day 15 to 20. The highest pH (4.94) was recorded with SBCS treatment and it was not significantly different ($p < 0.05$) from other treatments except BW and SBBW treatment. However, BW treatment recorded the lowest pH (3.8) and it was also not

significantly different ($p < 0.05$) from SBBW. The changes in pH of Pectomech that occurred after 20 days of storage following the different waxing treatment are shown in figure (4.2.7.).

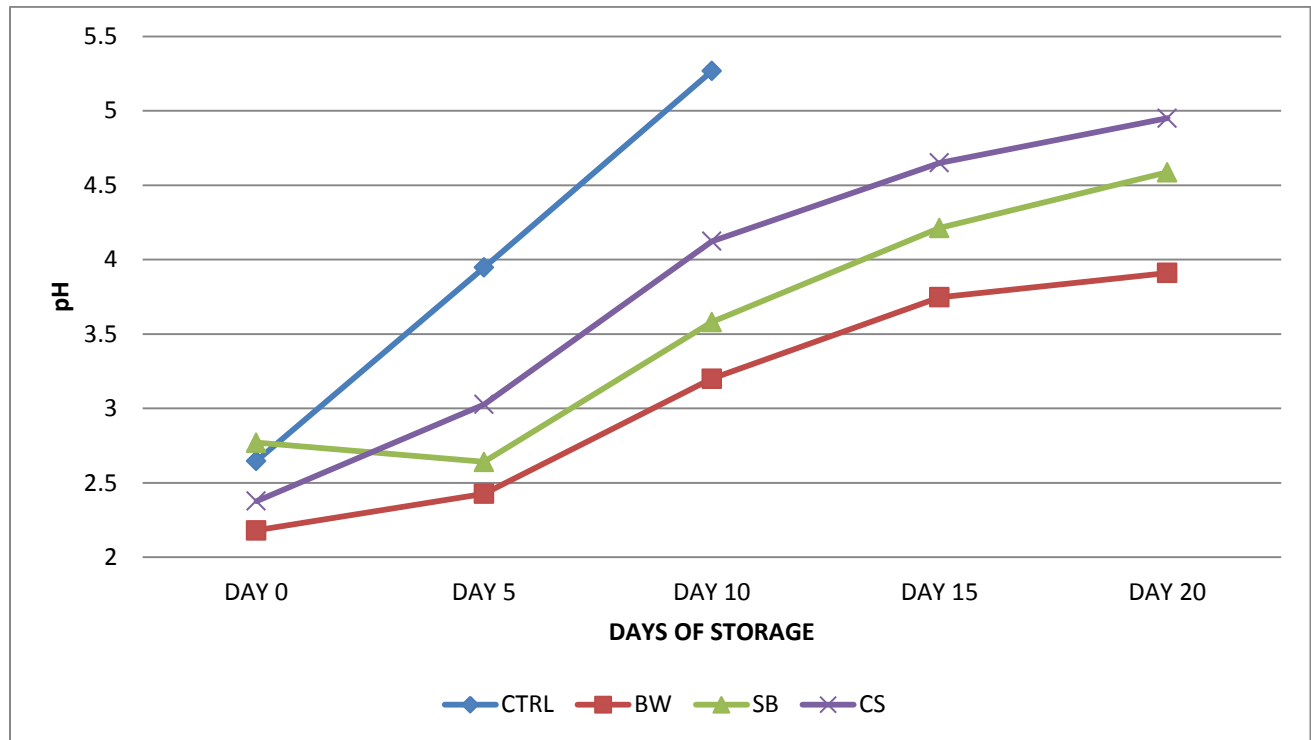


Figure 4.2. 7a Changes in pH following different waxing treatments on Pectomech

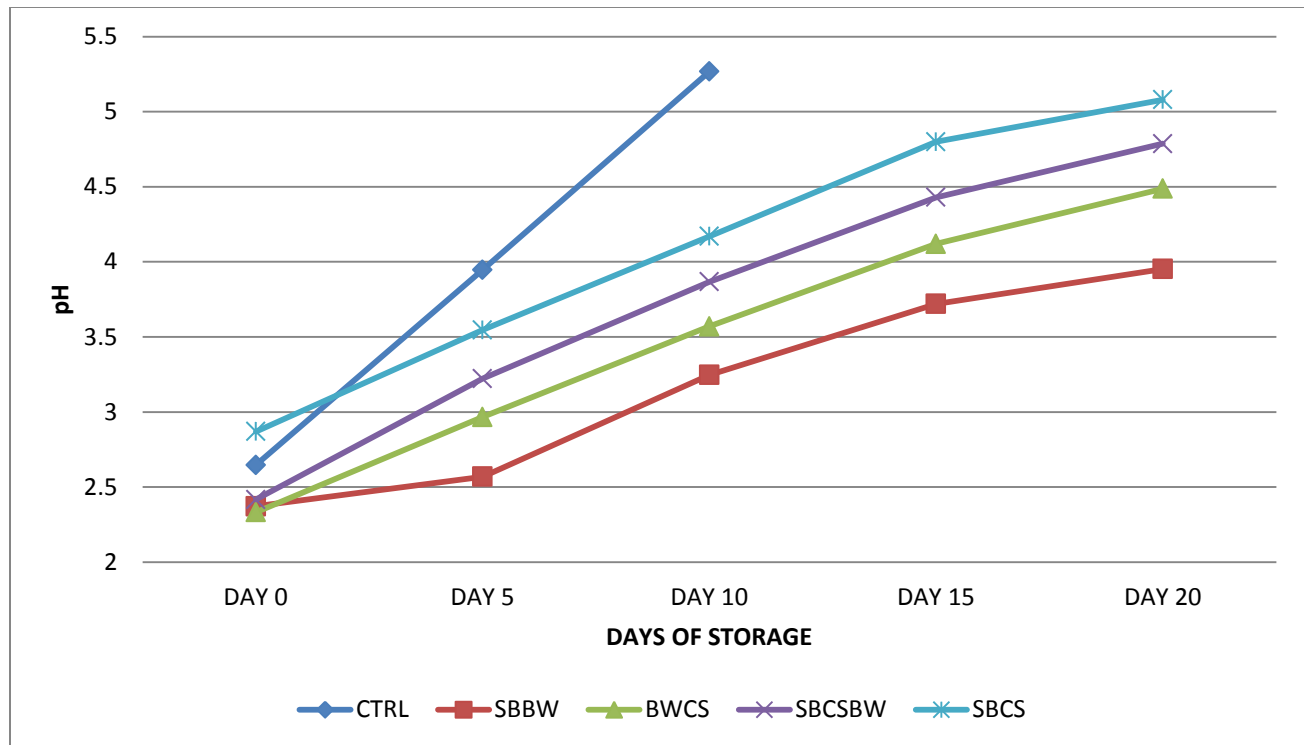


Figure 4.2. 7b Changes in pH following different waxing treatments on Pectomech

For Power, there was also a significance increase in pH from day 0 to day 20. However from day 0 to day 10, the control treatment recorded the highest pH (3.86) and was not significantly difference ($p < 0.05$) from the other treatment and their combinations. BW treatment recorded the lowest pH (2.64) and was significantly different ($p < 0.05$) from other treatment and their combinations. The study also showed that there was significant effect ($p < 0.05$) on pH as a result of waxing/variety interactions. Day 15 to 20 also followed a similar trend. The highest pH (5.07) was recorded with SBCS treatments and was not significantly different ($p < 0.05$) from the other treatment and their combinations. BW treatment fruits had the lowest pH (3.8) and was significantly different ($p < 0.05$) from the pH of fruits of the other treatments and their combinations (Appendix 1.8). The changes in pH of Power fruits that occurred after 20 days of storage following waxing/variety effect are shown in figure (4.2.8).

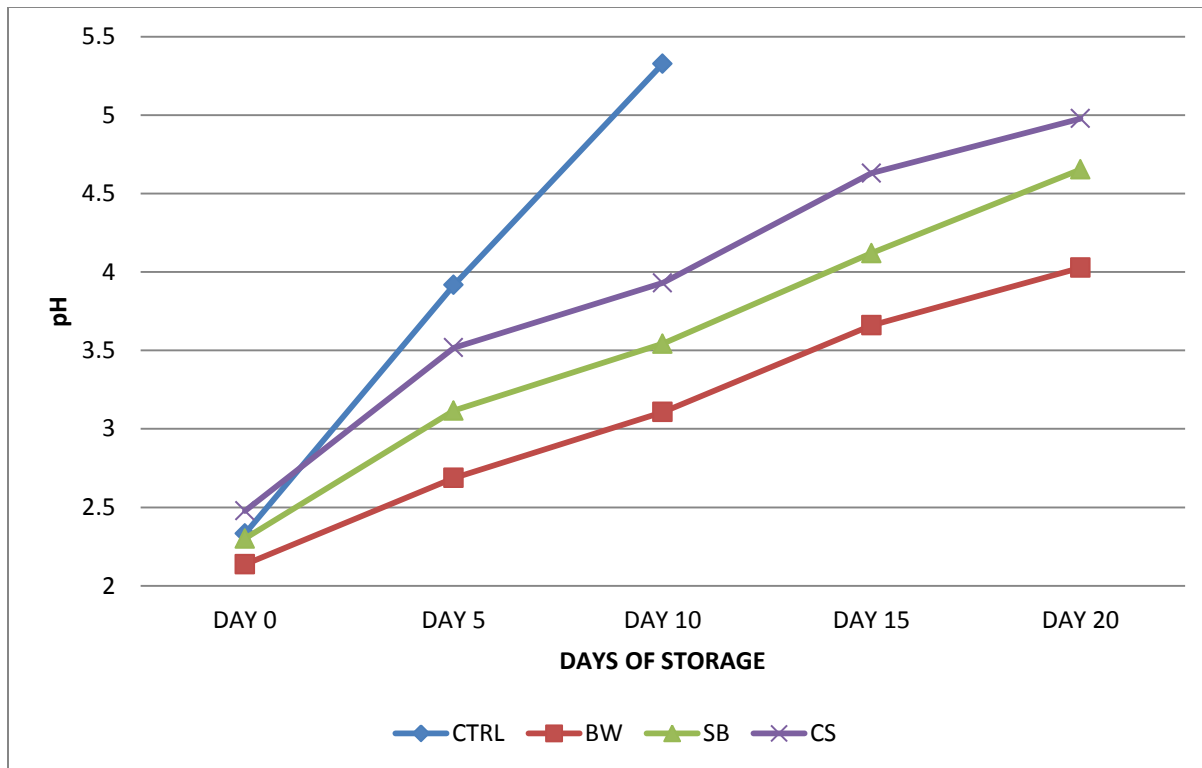


Figure 4.2. 8a Changes in pH following different waxing treatments on Power variety

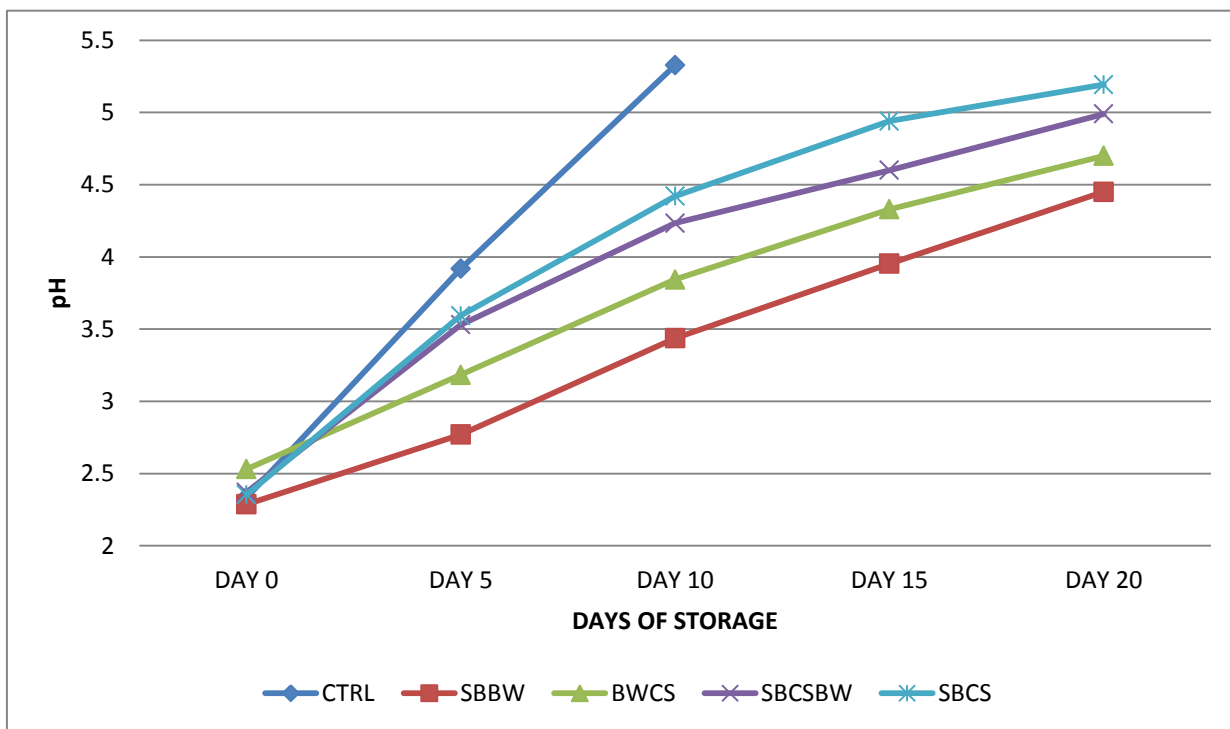


Figure 4.2. 8b Changes in pH following different waxing treatments on Power variety

4.2.6. Shelf life of tomato varieties following different Waxing treatment.

The storage life of the two tomato varieties following the different waxing treatment is shown in figure 4.2.9. The study revealed that the control for Pectomech and Power had a shelf life of 12 days and 10 days respectively. However, tomato fruits treated with different waxing material lasted for 20 days and above. In Pectomech, BW treatment had the longest shelf life of 34 days whiles CS treatment had the shortest shelf life of 23days for the treated samples. For the Power variety, the longest shelf life was recorded with BW treatment (28 days) whiles the shortest shelf life was recorded with CS treatment (22 days).

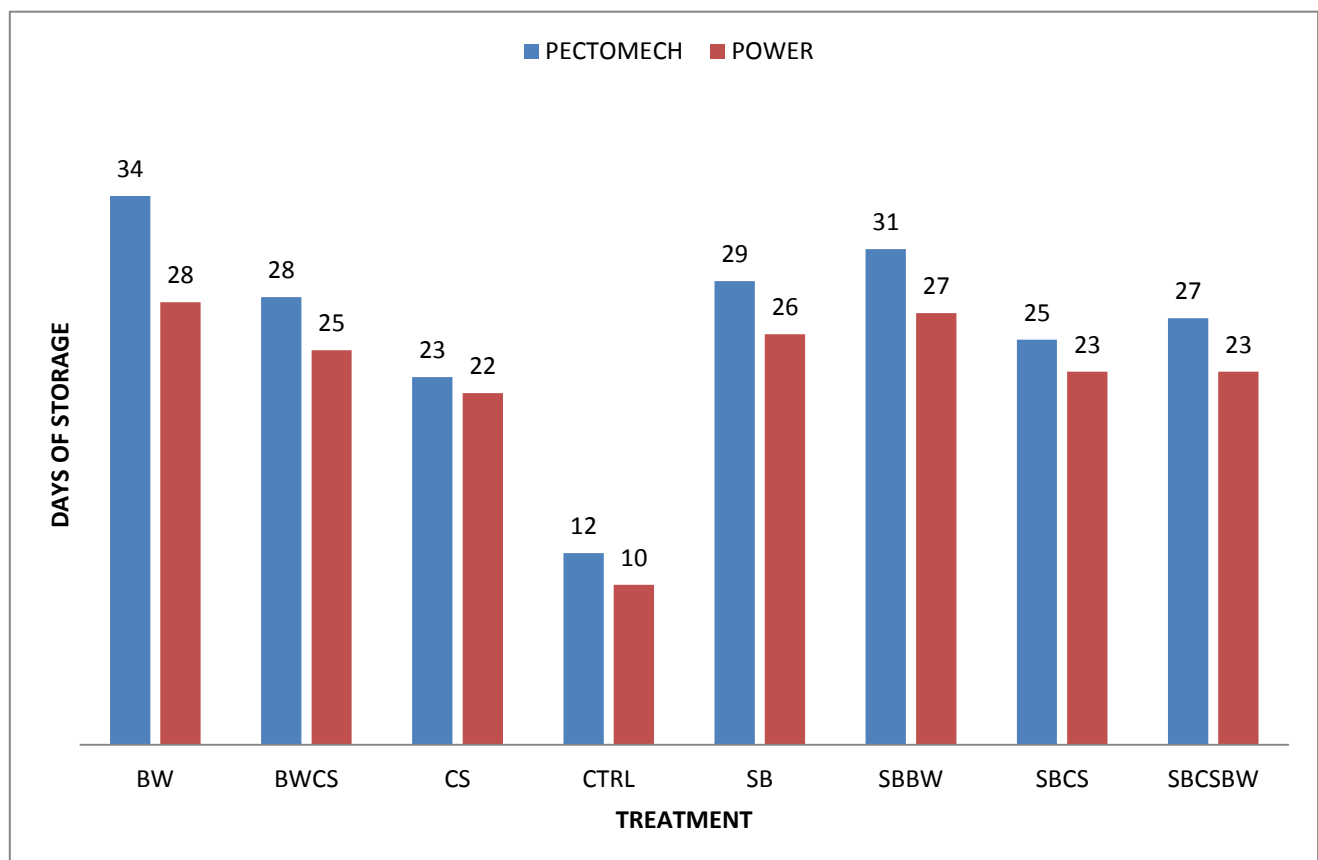


Figure 4.2. 9 Shelf life of tomato varieties following different waxing treatments

4.2.7. External colour of tomato varieties following different waxing treatment.

The study showed that there was significant increase in external colour as the days of storage progressed from day 0 to 20. There was also significant differences ($p < 0.05$) in waxing and varietal effect as well as their interactions. However, the control fruits for both varieties increased in colour sharply from day 0 to 5 and dropped sharply from day 5 to 10 but the treated fruit increased gradually from day 0 to 5 and maintained a uniform colour up till day 20 when a change in the colour was observed (Figures 4.2.10 and 4.2.11).

For Pectomech, the highest value for external colour from day 0 to 10 was recorded with the control treatment (73.18) and was statistically different ($p > 0.05$) from the other treatments and their combinations. The BW treatment recorded the lowest value (57.54) and was significantly different ($p < 0.05$) from the other treatment and their combinations except SBBW treatment. There was no significant difference ($p < 0.05$) between the external colour of CS, SBCS, and SBCSBW treatments (Appendix 1.9). However, from day 15 to 20, SBCS had the highest value for external colour (71.59). BW treatment recorded the lowest value for external colour (60.64) and was significantly different ($p < 0.05$) from the other treatment and their combinations. There were no significance differences among BWCS, CS, SBCS, SBBW and SB treatments.

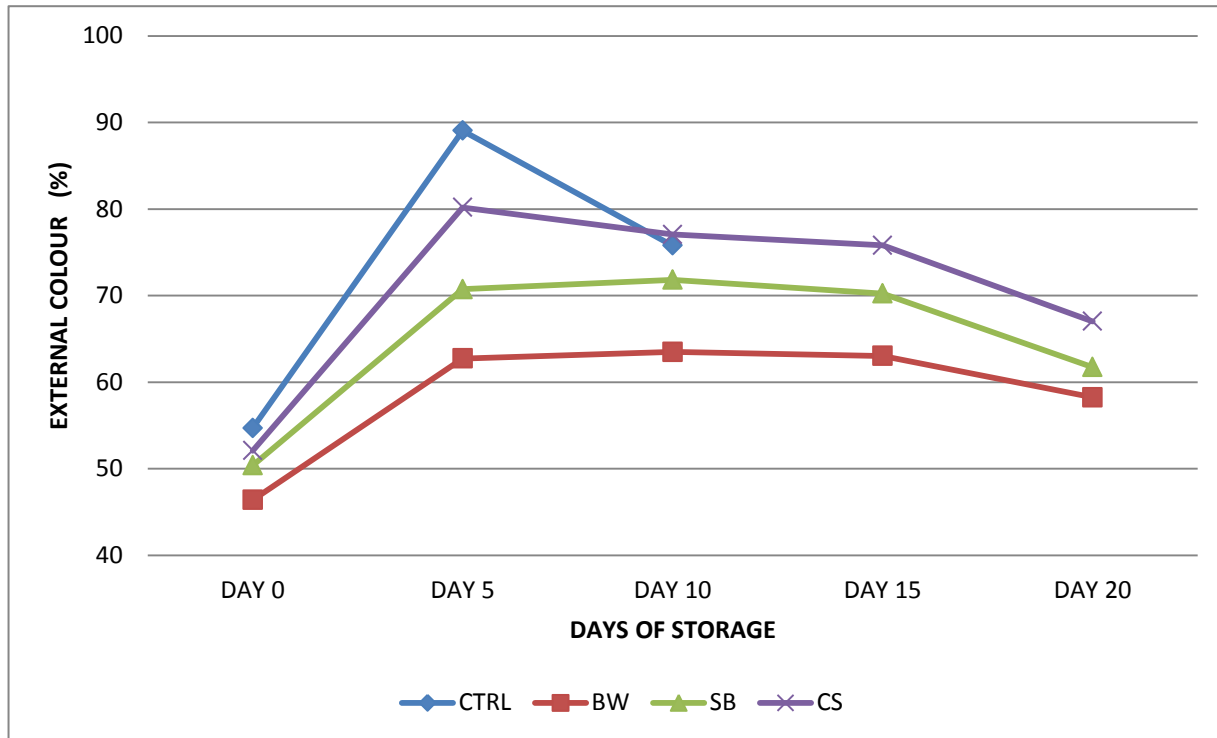


Figure 4.2. 10a Changes in External colour following different waxing treatments on Pectomech

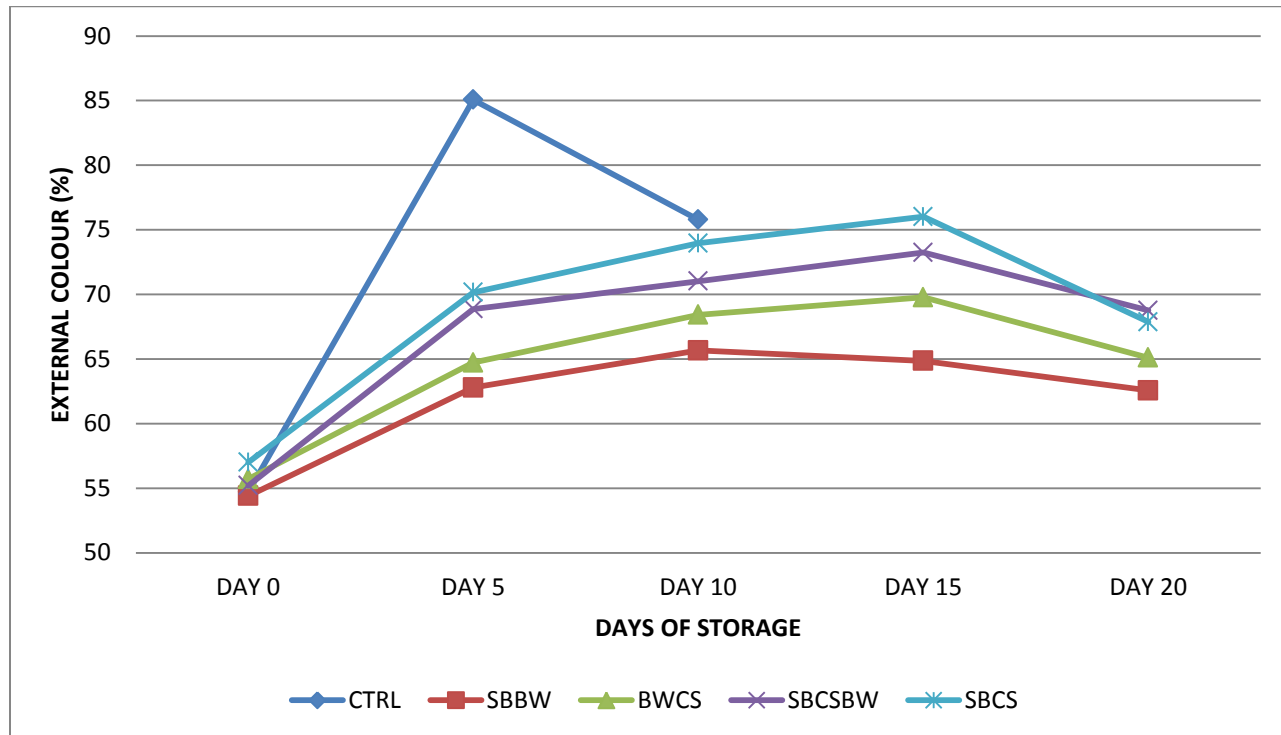


Figure 4.2. 10b Changes in External colour following different waxing treatments on Pectomech

For Power, the highest value for external colour from day 0 to 10 was recorded with the control fruits (74.52) and it was significantly different ($p < 0.05$) from the other treatment and their combinations. The BW treatment recorded the lowest value for external colour (57.09). There was no significant difference ($p < 0.05$) between BWCS, CS, SBCS and SBCSBW. However, from day 15 to 20, the highest value for external colour was recorded with SBCS treatment (71.94) and was significantly different ($p < 0.05$) from the other treatments. BW treatment recorded the lowest value for external colour and was not significantly different ($p < 0.05$) from SBBW treatment (Appendix 1.9). Generally, colour development was similar for both varieties. The results also suggest that waxing or edible coating delayed to a higher extent, ripening of tomato fruits during the storage period.

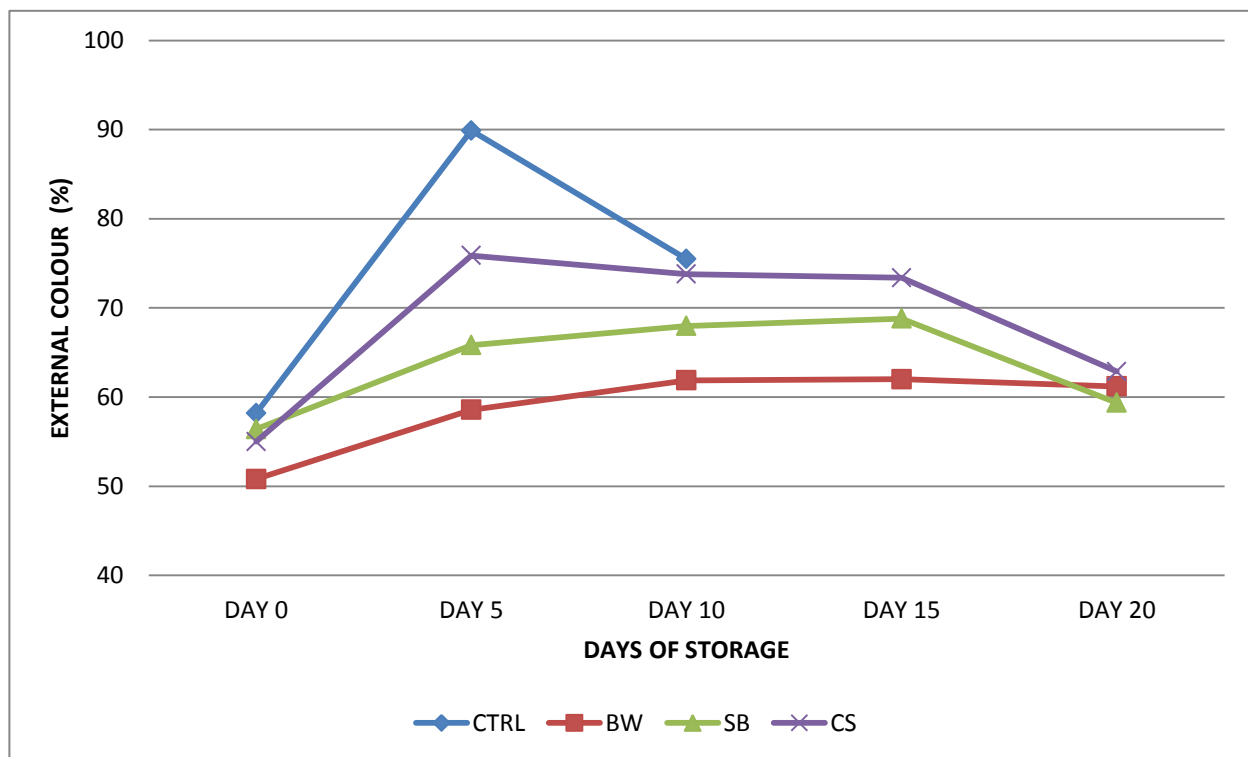


Figure 4.2. 11a Changes in External colour following different waxing treatments on Power tomato variety

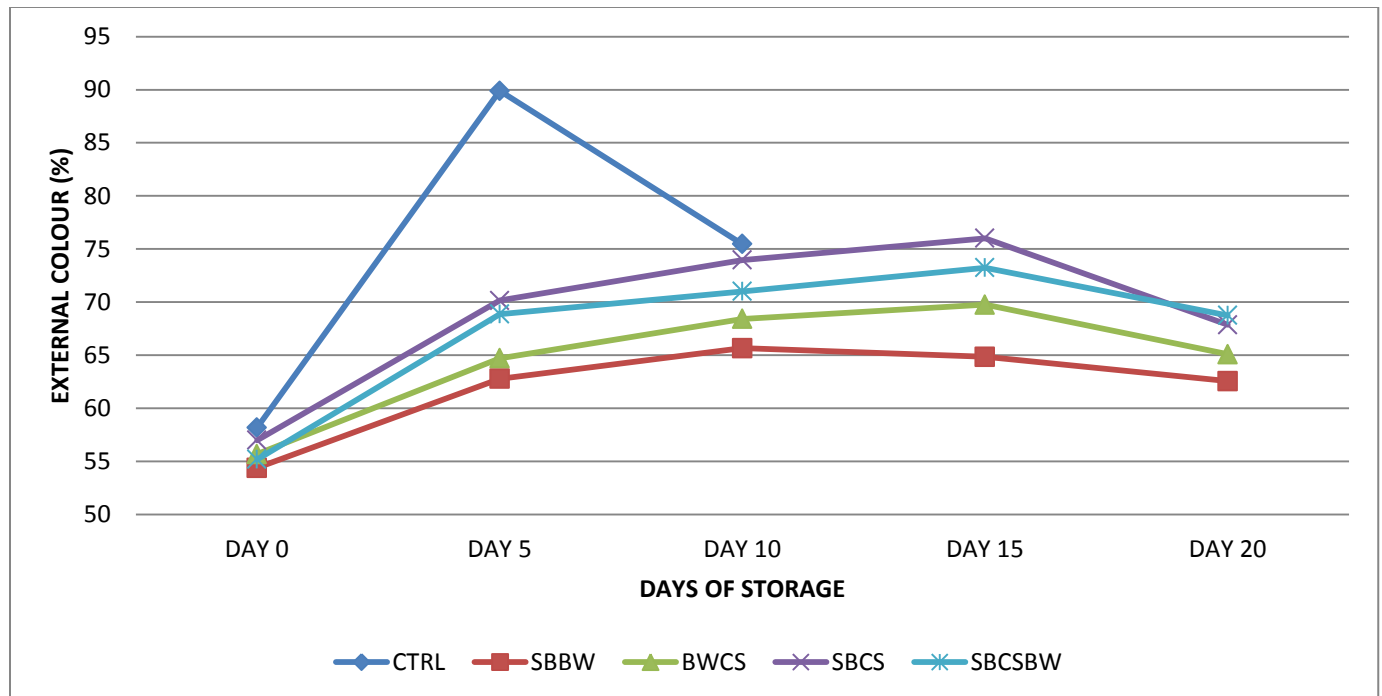


Figure 4.2. 12b Changes in External colour following different waxing treatments on Power tomato variety

4.3.1. Sensory evaluation of tomato varieties following different waxing treatment.

The study revealed that there were significant effects of waxing/variety interaction on all the sensory attributes except for skin colour of fruits for both varieties (Table 4.3.1).

The BW treatment had a significantly higher effect on all the sensory attributes of Pectomech fruits, whilst the control fruits had the lowest effect on all the sensory attributes. In terms of attractiveness, BW treatment was preferred by majority of the panelist to the other treatments except the control. Similarly, there were no difference in effect on smell between treatments accepts fruits coated with CS which was preferred to the control fruits. The effect of waxing on firmness was significantly higher in BW treatment than other treatments but there was no difference between SBBW and BWCS coated fruits. Fruit coated with SB was chosen over the other treatments but there was no difference between SBCSBW and SBCS treatments. Effect on

overall acceptability showed that there were differences between fruits coated with CS and the control but there were no differences between the remaining treatments (Table 4.3.1).

Table 4.3. 1 EFFECT OF DIFFERENT WAXING MATERIAL ON THE SENSORY ATTRIBUTES OF PECTOMECH TOMATO VARIETY

WAX	ATTRACTIVENESS	FIRMNESS	SKIN COLOUR	SMELL	OVERALL ACCEPTABILITY
BW	3.40a	4.30a	3.60	3.93a	3.63a
SBBW	2.98a	3.93a	3.97	3.73a	3.57a
BWCS	2.83a	4.20a	3.10	3.70a	3.41a
SB	2.77a	3.17b	3.00	3.40a	3.00a
SBCSBW	2.37a	3.76c	2.90	3.66a	3.30a
SBCS	2.33a	2.80c	2.63	3.27a	3.07a
CS	2.27a	2.57d	3.20	3.17b	2.80b
CTRL	2.03b	1.80e	2.50	2.13c	1.97c

All means sharing same letters are statistically non-significant at 0.05 probability level.

For Power, it was observed that waxing had significant effect on attractiveness, firmness, smell and overall acceptability. In terms of attractiveness, fruits coated with BW were most preferred by the panelist to fruits coated with the other types of wax, with the exception of control fruits all the other coatings had the same level of attraction. The panelist judged fruits coated with BW to have maintained the firmness better than fruits coated with the other waxing materials and their combinations except the control which was slightly firm. The study also revealed that fruits coated with BW were accepted than other treatments and their combinations in terms of smell, but judged SBCS, CS and control fruits as unpleasant. With respect to overall acceptability, fruits coated with BW were most accepted by the panelist than the other treatments and their combinations; however the acceptance level was statistically the same with fruits treated with SB, SBCS and CS. (Table 4.3.2). In all, treated fruits were accepted than the control fruits.

Table 4.3. 2 EFFECT OF DIFFERENT WAXING MATERIAL ON THE SENSORY ATTRIBUTES OF POWER TOMATO VARIETY

WAX	ATTRACTIVENESS	FIRMNESS	SKIN COLOUR	SMELL	OVERALL ACCEPTABILITY
BW	4.07a	3.87a	3.63	4.17a	4.17a
SBBW	3.27b	3.87a	4.73	4.13a	3.90b
BWCS	2.97b	4.07a	3.57	4.03a	3.50c
SB	2.70b	3.40a	3.17	3.30c	2.90d
SBCSBW	2.67b	3.60a	3.00	4.00b	3.30c
SBCS	2.57b	3.13a	3.07	3.27c,d	2.87d
CS	2.27c	3.13a	3.37	3.27c,d	2.87d
CTRL	1.73d	1.37b	2.23	2.07e	1.93e

All means sharing same letters are statistically non-significant at 0.05 probability level.

CHAPTER FIVE

5.0 DISCUSSION

5.1.0. POSTHARVEST MANAGEMENT PRACTICES ALONG THE TOMATO VALUE CHAIN IN FANTEAKWA DISTRICT

5.1.1. Pre-harvesting practices

The study revealed that the tomato value chain started from pre-harvesting stage which involved land preparation, nursing of seed and transplanting of seedlings into the field. Maintenance activities such as pruning, staking, weed, insect pest and disease control were carried out at regular intervals until fruits are harvested at physiologically matured stage. These findings are similar to the findings of Obeng-Ofori *et al.*, (2007), who reported that tomato seeds are sown in the nursery and the seedlings are transplanted with the first true leaf at the ground level into the field. According to Grubben and Denton (2004), staking and pruning are very important in tomato production. Staking prevents the plant from lodging during strong wind. It also prevents the fruits from touching the ground. Pruning is also another important practice which is the removal of unwanted parts of the plant. This allows free circulation of air throughout the central parts of the plant. Pruning the lateral shoots is often practiced to produce fruit of good and uniform size (Grubben and Denton, 2004).

5.1.2. Harvesting Practices

Harvesting marks the end of the growth cycle of tomatoes and the beginning of a series of stages of very important activities that ensure that the consumer gets the vegetable in the preferred state and at the best desired quality. Harvesting fresh-market tomatoes is labor intensive and requires multiple pickings (Orzolek *et. al.*, 2006). Results from the survey showed that majority of

farmers (92%) harvested fruits when they are fully ripened whilst 8% harvest half ripe fruits. About 76% of farmers harvested in the morning, 6% in the afternoon and 18% have no specific time of harvest. All farmers interviewed harvest their produce manually by hand twisting to break off the stalk. Harvesting was done manually either directly into boxes (bins) or first into buckets and emptied into the boxes. Some farmers used hired labour to harvest produce. This result confirms earlier works that have been reported by several researchers. Yeboah (2011) reported that, irrespective of the distance to the target market, tomatoes were harvested at the red-ripe state. According to Orzolek *et al.* (2006), tomatoes for the wholesale market should usually be picked at the mature green to breaker stage to prevent the fruit from becoming over ripe during long transportation / shipping and handling. They recommended leaving tomatoes on the vine to ripen if they can be brought to market quickly and in good condition. When market is available, tomatoes should be vine-ripe before harvesting. Usually, fresh market tomatoes are harvested by hand with harvesting operation varying among growers. This is usually the case with most growers in Ghana. Norman (1992) reported that fruits should be harvested early in the morning or in the evening to reduce field heat. At harvest the fruit must be handled with care to reduce bruises, cuts and injuries. Similarly, Genova *et al.* (2006) reported that harvesting activities should be completed during the coolest time of the day, which is usually in the early morning and produce should be kept shaded in the field and handled gently. Hurst (2010) advises that a good harvesting management is one that especially picks high quality tomatoes, since the riper the tomato, the more susceptible it is to bruising. He also advised harvest crew to carefully place fruits into picking containers instead of dropping them since a drop of more than 6 inches onto a hard surface can cause internal bruising that is not evident until after the tomato is cut open.

5.1.3. Sorting and Packaging

The use of appropriate packaging is an important physical control method of protecting produce from pest infestation, bruises, cuts and injuries in order to reduce losses and ensure that produce reaches the consumer in the best possible condition (Cornelius and Obeng-Ofori., 2008). The present study showed that all the farmers sorted fruits into sizes before packaging them for the market. The study also showed that 16% of the respondents packed the fruits in shallow wooden boxes, 66% in long big wooden boxes and 2% in plastic baskets, while 16% in cane baskets. These packaging materials were reported to be cheap and mostly available to the respondents. These observations are consistent with the work of several researchers. Obeng-Ofori *et al.* (2007), noted that, for local markets, the fruits are packed in baskets, cardboard boxes, and wooden crates and transported over long distances, especially from the northern parts of Ghana to the attractive markets in the south. According to FAO (2008) and Nasrin *et al.* (2008), fruits have soft cover which can easily be destroyed and attacked by microbes which bring deterioration. Packages should be designed to have sufficient openings for allowing air ventilation to the fruits. However, the cost of packaging materials has escalated sharply in recent years, hence poor quality; lightweight containers are preferred by farmers and traders which easily cause damage by handling or accelerate moisture loss (Vitroy, 2008). Stacking of non-uniform containers should also be done with care to prevent collapse of weaker packages and heavier cartons should always be placed at the bottom of a stack (Kitinoja and Gorny, 2009).

5.1.4. Transportation

Tomatoes are highly perishable in nature hence efficient means of transportation is necessary. The study revealed that about 92% of respondents usually transported their produce from the

farm to the point of sale by vehicle while 8% of respondents transported their produce by head-porter. About 42% of respondents use open truck, 34% use van or roofed truck and 24% use taxi in transporting their produce. These results are in agreement with Yabalola *et al.*, (2008), who reported that open truck vehicle and the taxis are appropriate since they don't expose the fruit to direct solar radiation which will cause premature senescence and subsequent reduction in shelf life. It can, however, cause mechanical injury and internal damage as a result of vibration during transportation which lowers shelf life and market value. The mode of transport also contributes to mechanical and physiological damage to fruits. Meanwhile, the accumulation of unarranged packed fresh fruit in vehicle during transportation may also lead to increased heat due to metabolic reaction of the cells and it may accelerate their mechanical damage. The breakdown of vehicles can be a significant cause of losses in some areas as perishable produce can be left in the sun for a day or more while repairs are carried out. The existence of poor infrastructure, poor nature of roads and transportation facilities causes up to 40% losses (Mehmood *et al.*, 2011).

5.1.5. Storage Practices

The main objective for storing fruits after harvest is to control the rate of ripening to extend the shelf life. The results from the survey revealed that all the farmers and traders are not able to store their produce in case there is no ready market. The study also showed that farmers rather preferred leaving the fruits on the farm to rot when there is no ready market while traders preserved their produce by pouring the fruits on bare cemented or wooden floor when there is no ready market. These results confirm similar findings by Orzolek *et al.*, (2006), that where there is unavailable storage facility and poor access to markets, farmers had no choice but to leave their produce in the fields to rot. Yeboah (2011) also noted that the commonest storage methods used

by farmers and traders included spreading the produce on the bare floor with only a few small scale traders storing their produce in refrigerators. Keeping the produce on the bare floor may reduce the temperature of the produce hence the rate of respiration.

5.1.6. Causes of postharvest losses of tomatoes

Losses of horticultural produce are a major problem in the post-harvest chain. They can be caused by a wide variety of factors, ranging from growing conditions to handling at retail level. Post-harvest loss occurs between the completion of harvest and moment of human consumption. It is thus loss, which happens after separation of the product from the medium and site of immediate growth or production of the product (Cornelius and Obeng-Ofori, 2008). Major losses in tomato quality and quantity occur between harvest and consumption (Brooks *et al.*, 2008). Results from the survey showed that 34% of farmers interviewed indicated that lack of markets is the major factor responsible for the pre-harvest and postharvest losses of tomatoes. 32% attributed it to lack of storage technology, 20% to lack of storage facility, 8% to lack of transport for harvested produce, 4% attributed it to pest and disease and 2% of farmers attributed loss of their produce to the lack of a processing plant. On the other hand, traders experienced losses of their produce and most of the losses were recurrent. In all, 54% of traders attributed losses to lack of storage technology. This followed by lack of market (34%), lack of transport for produce (4%), lack of storage facility (4%) and pest attack and disease (2%) was considered the least cause of losses by traders. These results are consistent with the findings of Robinson and Kolavalli (2010), who observed that in Ghana, the agricultural sector in general and the tomato sector in particular have not met their potential. In this sector, production seasonality, the dominance of rain fed agriculture, high perishability of the vegetable, lack of

ready market, lack of a reasonable alternative uses of the vegetable and poor pricing are some of problems faced by farmers. In addition, it is probable that, poor postharvest practices coupled with poor handling and storage technology account for the recurrent seasonal postharvest losses of tomatoes. Most often also, losses of fresh vegetables occur along the long chain of supply from the producer to the consumer. Losses occur at the stages of sorting, packaging, storage, transport and marketing stages of the life of fresh horticultural produce (Kitinoja, 2008). These results are also in agreement with Yeboah (2011) who reported that lack of appropriate storage facilities and storage technology make it difficult for farmers to prolong the shelf life of their produce. Small market stalls with poor ventilation are not conducive enough for storage of tomatoes and this adds to the external factors that have already reduced the shelf life of the produce such as injuries and field heat accumulation. Similar works by Bani *et al.* (2006) in a research conducted in Ghana to assess loss of tomatoes from Bolgatanga to Accra revealed that loss along the route alone amounted to 20%. Not only are losses clearly a waste of food, but they also represent a similar waste of human effort, farm inputs, livelihoods, investments and scarce resources such as water (World Resource Institute, 1998).

5.1.7. Type of losses in the postharvest chain.

The study revealed that the type of losses along the tomato postharvest value chain included mechanical, biological (rotting) and physiological losses. During harvesting the losses that occurred were mechanical losses (50%), rotting (14%) and physiological loss (36%). In sorting and packaging, the losses that occur include mechanical losses (82%), rotting (12%) and physiological losses (6%). During storage, 80% of respondent mention rotting, 16% mentioned mechanical losses and 4% mentioned physiological losses. In transportation, 84% mentioned

mechanical losses, 2% mentioned rotting and physiological loss as the main causes of loss that occur during transportation. According to Bani *et al.* (2006), tomatoes are highly perishable and very susceptible to mechanical damage during poor handling and transportation. The high mechanical damage losses could be explained by the fact that most fruits are harvested by shaking trees or by picking them when they fall down. Moreover, mechanical damage can cause internal bruising which results in physiological damage or splitting and skin breakage, thus rapidly increasing water loss and the rate of normal physiological breakdown.

5.1.8. Farmers and traders perception on waxing of tomato fruits.

The study showed that all farmers and traders do not employ waxing for the preservation of their tomato fruits. The study also showed that 94% of farmers and 86% of traders were willing to accept new effective methods of preservation of tomato fruits. According to Gonzalez-Aguilar *et al.*, (2010), mineral oil coating could be a good alternative to preserve the quality and extend the postharvest life of tomato fruit. Nurul (2012) reported that the effect of cassava starch coating on fresh-cut pineapple reduced weight loss, loss of firmness, respiration rate, delayed the change in colour, maintained pH, total soluble solid as well as quality of the pineapples. The effect of shea butter as a food-grade wax on plantain varieties prolong the shelf life and maintain their sensory qualities. The use of shea butter as a food-grade wax can be further explored since no safety or residual effect is foreseeable (Sugri *et al.*, 2010). Shahid *et al.*, (2011) also reported that the effect of bee wax coatings on physiological changes in fruits of sweet orange maintained weight loss, firmness, pH, TSS and titratable acidity.

5.2.0. EFFECT OF WAXING ON THE QUALITY CHANGES OF TOMATO FRUIT

5.2.1. Percentage Weight loss (% WL)

Weight loss means the amount of water lost from fruits or vegetables over a period and it is related to the shelf life of produce. In this study the percentage weight loss of the two tomato varieties increased with the storage period. Fruits stored at ambient tropical conditions lose weight due to respiration and transpiration. The lower loss in weight compared to control that was seen in fruit coated with different waxing materials are consistent with the findings of several researchers. Olivas *et al.* (2003) concluded that wax application largely contributed to the reduction in the weight losses of tomatoes. Edible coatings act as water-loss barriers, causing high relative humidity in the surrounding atmosphere of the tomato fruit and thus reducing the moisture gradient to the exterior (Park *et al.*, 1994, El Ghaouth *et al.*, 1992). Similar works by Mahajan *et al.* (2011), also suggests that the percent weight loss in general, increased with advancement of the storage period rather slowly in the beginning, but at a faster pace as the storage period advanced. Findings of Yuniarti and Suhardi (1992), showed that lower weight loss was observed in the case of treated mangoes as compared to control samples. Lim-Byung *et al.* (1998), showed that wax coating decreased the rate of respiration and transpiration, thus resulting in reduced weight loss, and increased shelf life. These results further affirmed the findings of Attia (1995), who reported that an increase in weight loss was observed with time. When fruits are waxed, it builds a moisture barrier that is able to prevent transpiration of water hence a lower loss in weight as compared to unwaxed fruits. Mejia-Tores *et al.* (2009) also noted similar trends in weight loss when tomatoes were waxed.

5.2.2. Firmness

Firmness is a critical quality index because it determines whether or not a fruit can be transported or shipped to distant markets without deteriorating. Tomato fruit soften as they develop from immature green to full red colour (Hanson, 2001).

This study showed that there was a significant decline in firmness from day 0 to 20 and the control fruits declined in firmness faster than the treated fruits. Mahajan *et al.* (2011), reported that fruit firmness declined with advancement in storage period and it was higher in the control fruit than the treated fruits. These results are in line with Gonzalez-Aguilar *et al.*, (2010a) who suggested that the edible coatings significantly ($p < 0.05$) reduced water and increased firmness in tomato fruit during storage. Similar views have been expressed by El Ghaouth *et al.*, 1992; Sidhu *et al.*, 2009). Coated soft pear, kinnow, and apple fruits have been reported to maintain firmer fruits (Bishnoi *et al.*, 2009; Mahajan *et al.*, 2002). These results are in line with the findings of Ladaniya and Sonker (1997) who reported that maximum retention of natural freshness and firmness was observed in Nagpur mandarin when fruits were waxed and stored for up to 21 days of storage.

5.2.3. Total Soluble Solids (TSS) or % Brix.

The total soluble solids are the amount of sugar and soluble minerals present in fruits and vegetables. The results showed that, there was a significant ($p < 0.05$) increase in total soluble solids (TSS) from day 0 to 10 and a gradual decline from day 10 to 20 for both Power and Pectomech tomato varieties. The increase in TSS from day 0 to day 10 may be due to hydrolytic changes in the starch concentration during the post harvest period. These changes result in the conversion of starch to sugar, which is an important index of ripening process (Kays, 1997).

Ladaniya and Sonker (1997) reported maximum retention of TSS when fruits were waxed and stored for up to 21 days. Gul *et al.* (1990) also found that TSS increased slowly in wax coated blood red orange fruits than control during storage. Syamal (1991) reported that the total soluble solids increase during ripening. During normal ripening, the total soluble solid tend to increase through the stages of maturity. Symal (1991) indicated that the slow increase might be due to use of waxes which affect the activity of mitochondria and some enzymes. However, the gradual decline of TSS from day 10 to 20 for both varieties may be due to more utilization of sugars than conversion of complex carbohydrates into simple sugars by the fruit to fulfill energy demand. This is consistent with the findings of Yau *et al.*, (2010), who reported that TSS in watermelons reduced significantly following 14 days of storage. He indicated that the decline in TSS was due to the rate of respiration or oxidation during the storage period. During respiration, there is an oxidative breakdown of complex molecules such as starch, sugars and organic acids into simpler molecules such as carbon dioxide and water (Yau *et al.*, 2010). From this study it was observed that Power variety retained significantly higher levels of TSS than the pectomech variety.

5.2.4. Total titratable acidity.

The test that measures all the acids present in a given fruit is referred to as total titratable acidity (TTA). The study showed that there was a significant ($p < 0.05$) decrease in TTA from day 0 to day 20 for both varieties and the control fruits had lower levels of total titratable acids compared to the treated fruits According to Hu *et al.*, (2011), wax treatment reduced titratable acidity of pineapple kept under cold storage conditions by approximately 6% and 5 % compared with the control at 21 days of storage. Lim-Buying *et al.*, (1998) also observed that Prowax F coating on apples during room storage decrease titratable acidity faster in control fruits than in wax coated

fruits. The decrease in acidity was due to the accumulation of CO₂ internally in the fruits tissue which causes acidosis after dissolving and forming carbonic acid (Carrillo *et al.*, 1995). Disappearance of malic and citric acid during ripening process may be the main factor responsible for the reduction in titratable acidity during the storage. Similar works by Jiang and Li (2001) showed that wax coating on longan fruit decreased titratable acidity during storage. Shahid *et al.* (2011) also reported that bee wax coatings of sweet orange decreased TTA during the storage period. In general, fruit acidity tends to decrease with maturation and a concomitant increase in sugar content (Raffo *et al.*, 2002).

5.2.5. pH

pH of fruits and vegetables is the measure of the strength of the acids in them. Results from the experiments showed that there was a significant increase in pH from day 0 to 20. Padmini (2006) reported that the pH of the fruit increases throughout development. The increase in pH is in agreement with Oyeleke and Odedeji (2011) who discovered that pawpaw fruits treated with palm kernel oil retained a higher pH than bee waxing treatment and chemical waxing treatment. Similar works done by Shahid *et al.*, (2011), revealed that increase in pH in wax treated fruits might be due to high rate of metabolic activities, hence acidity decreased but pH increased and result in high TSS contents. The authors attributed the change in pH during storage period to a number of reasons. First, the alteration of biochemical condition of fruit due to wax treatments and secondly due to lower rate of respiration and metabolic activity. They further reported that pH increase but at a slower rate particularly at the end of storage period. These results are similar to findings of Biasi and Zanette (2000) who reported that gibberellic acid and wax solution had slight increased pH with storage.

5.2.6. External colour.

The study showed that there was significant increase in external colour as the days of storage progressed from day 0 to 20. The colour development was similar for both varieties. The waxing or edible coating delayed to a larger extent, the ripening process of tomato fruits during the storage period. These results are consistent with the findings of Zapata *et al.*, (2008), who reported that one alternative to modify the ripening process is the use of edible coatings. The delay of red colour formation of coated tomatoes is related to the modification of the internal atmosphere of the fruit, which produces high CO₂ and low O₂ levels that affect the maturation process. Mejia-Torres *et al.* (2009), observed that waxed fruits showed a delay in colour development and ripening and attributed it to a delay in chlorophyll degradation and lycopene synthesis.

5.2.7. Shelf life.

Storage life refers to the period between when fruits are harvested and the time the fruits become unfit for sale or consumption. The study revealed that the control for Pectomech and Power variety lasted for 12 days and 10 days, respectively. However, waxed tomato fruits irrespective of the waxing materials stored for more than 20 days. The shorter storage life of the control fruit may be due to the higher respiration rate that occurred among the unwaxed fruits. On the other hand, the longer storage life of the treated fruit could mean that the waxing material slowed down the rate of respiration and did not encourage the rapid exchange of carbon dioxide and oxygen. This result is similar to the findings of Gonzalez-Aguilar *et al.*, (2010a), who reported that the use of a mineral oil treatment preserved the quality of tomato fruit to the greatest extent and concluded that mineral oil wax could be a good alternative for preserving the quality and

extending the shelf life of fresh tomato fruit. Shahid *et al.* (2011) reported that bee wax coating was very effective in improving the overall quality and extending the shelf life of sweet orange fruits at room temperature. Nurul (2012), also reported that cassava starch coating on fresh-cut pineapple delayed the change in colour, maintain quality of the pineapples and prolong the storage life. Sugri *et al.* (2010), also noted that shea butter as a food-grade wax on plantain varieties prolong the shelf life and maintain their sensory qualities.

5.3.1. Sensory Evaluation.

The waxed fruits performed better than the unwaxed fruits irrespective of the variety used in terms of the sensory attributes. The panelist preferred treated fruits than the untreated fruits considering all the sensory attributes. As far as the panelists were concerned, wax treatment did not affect skin colour. Fruit coated with BW treatment and its combinations were the most accepted over the other treatments. Lamptey (2013) reported that consumers showed strong acceptability for neem palm wax treatment on watermelon than the control treatment.

CHAPTER SIX

6.0. CONCLUSION AND RECOMMENDATIONS

6.1. Postharvest management practices along the tomato value chain in Fantekwa District.

From the study, the postharvest management practices along the tomato value chain start from pre-harvesting stages which include land preparations and ends finally with the consumer. Harvesting was done manually and majority of farmers harvest fruits when they were fully ripe. Majority of the farmers were aware that harvesting must be done in the mornings and the postharvest implication for late harvest. It was observed on some of the farms that harvested produce were poured from head height into bins due to the competition among the harvesting groups. All farmers and traders in the study area practiced sorting of fruits into sizes before packaging. The packaging materials that were used included wooden boxes, plastic and cane baskets. The inappropriate packaging practices by some respondents resulted in a lot of losses. All farmers and traders were unable to store produce when there was no ready market. The farmers preferred leaving the fruit to rot on the farms whilst the traders preserved their produce on bare cemented or wooden floor. Majority of the respondent transported their produce to the market by vehicle whilst few use head porters. The postharvest losses of tomatoes in Fantekwa district were observed to start on the farm during harvesting to the point of consumption. Postharvest losses of tomato fruit were seen to be a major problem that affected both farmers and traders in the district. The main causes of losses were seen to be lack of ready market, lack of storage technology, lack of storage facility, lack of transport for harvested produce, pests and diseases and lack of processing plants. The type of losses along the tomato postharvest value chain included mechanical, rotting (biological) and physiological losses. In all, postharvest

management practices involved in the tomato value chain in the district are not adequate to prevent losses.

To reduce postharvest losses of tomatoes, it is essential to handle fruits with care, especially during harvesting, packaging, and transportation operations. Vehicles used in transporting tomato fruits should be the types that are designed for carry agricultural goods. These may include trucks with cooling system and cushioning materials that mitigate the forces of impact responsible for causing cuts and bruises. It is also imperative to improve the knowledge and skills of farmers and traders on how to maintain fruits quality from the field to the points of sale so as to reduce postharvest losses. Farmer-Trader Associations should be formed to ensure a ready market for the produce.

6.2. The effect of different waxing materials on the quality changes of tomato fruits

The study showed that edible wax coatings were very effective in preserving the overall quality of the tomato fruits. All waxing treatments delayed the development of weight loss, firmness, pH, total soluble solids, and total titrable acidity of fruits. The results also suggest that the edible wax coatings delayed the ripening process and colour development of tomato fruits during the storage period and extended the shelf life. BW treatment and its combinations performed best than the other treatments. Thus, locally produced wax such as BW, SB, CS treatments and its combinations could be a good technology for preserving the quality and extending the shelf life of fresh tomato fruits as well as maintaining the physical and chemical properties. It is recommended that similar experiments should be carried out with the same locally produced wax under farmers' condition to verify the findings.

6.3. Consumer acceptability of waxed tomato fruits

It can be concluded from the study that consumers would be willing to buy and use waxed tomatoes. Additionally, the locally produced waxes such BW, SB, CS and their combinations improved some organoleptic and chemical properties such as attractiveness, firmness, smell and overall acceptability of waxed fruits. Generally, for stored tomatoes, consumers preferred waxed fruits to unwaxed fruits. Farmers and traders should be encouraged to use locally available wax materials to coat their produce and maintain the quality.

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APPENDIX 1

1.1. Effect of different waxing material on the % WL OF Pectomech						
	DAY 5	DAY 10	MEANS	DAY 15	DAY 20	MEANS
BW	2.69	8.41	5.55d	18.40	30.30	24.35f
BWCS	2.74	8.68	5.71d	23.40	34.80	29.10d
CS	2.32	15.98	9.15b	29.80	47.60	38.70a
CTRL	10.65	48.34	29.49a			
SB	2.58	13.41	7.99b	22.80	35.80	29.30d
SBBW	2.86	8.66	5.76d	21.90	33.90	27.90e
SBCS	4.13	13.22	8.68b	29.50	47.20	38.35b
SBCSBW	3.89	11.10	7.50c	21.10	45.90	33.50c
Fpr.(0.05)	<0.01	<0.01		<.001	<0.01	

Means sharing similar letters within columns are not significantly different from each other at LSD 0.05%.

1.2 Effect of different waxing material on the % WL of Power						
	DAY 5	DAY 10	MEANS	Day 15	DAY 20	MEANS
BW	4.45	7.36	5.91e	22.50	30.50	26.50f
BWCS	4.27	11.44	7.85e	32.00	54.00	43.00c
CS	3.60	19.11	11.36b	40.57	64.60	52.59a
CTRL	15.39	75.42	45.34a			
SB	2.77	10.97	6.88e	33.60	60.30	46.95b
SBBW	2.30	10.17	6.23e	23.10	36.90	30.00e
SBCS	2.01	17.82	9.92c	34.70	58.70	46.70b
SBCSBW	5.88	13.71	9.79d	29.90	52.90	41.40d
Fpr. (0.05)	<0.01	<0.01		<.001	<0.01	

Means sharing similar letters within columns are not significantly different from each other at LSD 0.05%.

1.3. EFFECT OF DIFFERENT WAXING MATERIAL ON THE TSS OF PECTOMECH							
	DAY 0	DAY 5	DAY 10	MEANS	DAY 15	DAY 20	MEANS
BW	1.70	3.56	4.05	3.10e	4.13	4.07	4.10d
BWCS	1.79	4.28	4.43	3.50c	4.67	4.67	4.67b
CS	1.58	4.46	5.35	3.80b	4.93	4.53	4.73b
CTRL	1.143	5.43	6.90	4.49a			
SB	1.52	4.22	5.13	3.62c	4.73	4.17	4.45d
SBBW	1.51	3.20	4.80	3.17e	4.60	4.63	4.62c
SBCS	1.49	4.10	5.07	3.55c	5.34	4.40	4.87a
SBCSBW	1.79	3.83	4.47	3.36d	5.17	4.33	4.75b
Fpr. (0.05)	0.149	<0.01	<0.01		<0.001	<0.001	

Means sharing similar letters within columns are not significantly different from each other at LSD 0.05%.

1.4. EFFECT OF DIFFERENT WAXING MATERIAL ON THE TSS OF P0WER							
	DAY 0	DAY 5	DAY 10	MEANS	DAY 15	DAY 20	MEANS
BW	1.55	4.00	5.57	3.70e	4.97	4.37	4.67e
BWCS	1.59	4.59	6.39	4.19c	5.47	4.87	5.17c
CS	1.71	5.09	6.93	4.58b	6.00	5.30	5.65a
CTRL	1.70	5.61	7.95	5.08a			
SB	1.72	4.67	6.16	4.18c	5.53	4.80	5.16c
SBBW	1.61	4.30	5.83	3.91d	5.30	4.60	4.95d
SBCS	1.49	4.83	6.53	4.29c	5.73	5.05	5.39b
SBCSBW	1.87	4.72	6.49	4.36c	5.62	4.97	5.29b
Fpr. (0.05)	0.149	<0.01	<0.01		<0.001	<0.001	

Means sharing similar letters within columns are not significantly different from each other at LSD 0.05%.

1.5. EFFECT OF DIFFERENT WAXING MATERIAL ON THE TTA OF PECTOMECH							
	DAY 0	DAY 5	DAY 10	MEANS	DAY 15	DAY 20	MEANS
BW	0.90	0.79	0.69	0.79a	0.60	0.50	0.55a
BWCS	0.83	0.78	0.64	0.75a	0.55	0.44	0.50b
CS	0.89	0.60	0.51	0.67c	0.40	0.33	0.36e
CTRL	0.85	0.50	0.28	0.55d	-	-	-
SB	0.88	0.69	0.58	0.72a	0.50	0.41	0.45c
SBBW	0.83	0.78	0.64	0.75a	0.55	0.44	0.50b
SBCS	0.88	0.68	0.55	0.70b	0.46	0.38	0.42d
SBCSBW	0.87	0.75	0.60	0.74a	0.50	0.40	0.45c
Fpr.(0.05)	0.421	0.111	>0.01		0.09	>0.01	

Means sharing similar letters within columns are not significantly different from each other at LSD 0.05%.

1.6 EFFECT OF DIFFERENT WAXING MATERIAL ON THE TTA OF POWER							
	DAY 0	DAY 5	DAY 10	MEANS	DAY 15	DAY 20	MEANS
BW	0.89	0.80	0.69	0.80a	0.59	0.48	0.54a
BWCS	0.86	0.60	0.51	0.66a	0.42	0.34	0.38d
CS	0.81	0.57	0.47	0.62a	0.35	0.27	0.31f
CTRL	0.84	0.45	0.25	0.52c			
SB	0.85	0.69	0.57	0.71a	0.48	0.36	0.42c
SBBW	0.85	0.75	0.61	0.73a	0.50	0.38	0.44b
SBCS	0.84	0.52	0.40	0.59b	0.31	0.27	0.29f
SBCSBW	0.85	0.56	0.44	0.62a	0.37	0.29	0.33e
Fpr.(0.05)	0.421	0.111	>0.01		0.09	>0.01	

Means sharing similar letters within columns are not significantly different from each other at LSD 0.05%.

1.7. EFFECT OF DIFFERENT WAXING MATERIAL ON THE pH of PECTOMECH TOMATO VARIETY							
	DAY 0	DAY 5	DAY 10	MEANS	DAY 15	DAY 20	MEANS
BW	2.18	2.43	3.20	2.60b	3.75	3.91	3.83b
BWCS	2.33	2.97	3.57	2.96a	4.12	4.49	4.30a
CS	2.36	3.03	4.12	3.18a	4.65	4.95	4.80a
CTRL	2.65	3.95	5.27	3.95a	-	-	-
SB	2.77	2.64	3.58	2.97a	4.21	4.59	4.40a
SBBW	2.37	2.57	3.25	2.73b	3.72	3.95	3.84b
SBCS	2.87	3.55	4.17	3.53a	4.80	5.08	4.94a
SBCSBW	2.42	3.22	3.87	3.17a	4.43	4.79	4.61a
Fpr.(0.05)	0.463	<0.01	0.609		<0.01	0.015	

Means sharing similar letters within columns are not significantly different from each other at LSD 0.05%.

1.8. EFFECT OF DIFFERENT WAXING MATERIAL ON THE pH of POWER TOMATO							
	DAY 0	DAY 5	DAY 10	MEANS	DAY 15	DAY 20	MEANS
BW	2.14	2.69	3.11	2.64b	3.66	4.03	3.84b
BWCS	2.53	3.18	3.84	3.19a	4.33	4.70	4.52a
CS	2.48	3.52	3.93	3.31a	4.63	4.98	4.80a
CTRL	2.33	3.92	5.33	3.86a			
SB	2.30	3.12	3.54	2.99a	4.12	4.65	4.39a
SBBW	2.29	2.77	3.44	2.83a	3.95	4.45	4.20a
SBCS	2.35	3.59	4.42	3.46a	4.94	5.19	5.07a
SBCSBW	2.37	3.53	4.23	3.38a	4.60	4.99	4.80a
Fpr.(0.05)	0.463	<0.01	0.609		<0.01	0.015	

Means sharing similar letters within columns are not significantly different from each other at LSD 0.05%.

1.9. EFFECT OF DIFFERENT WAXING MATERIAL ON THE EXTERNAL COLOUR OF PECTOMECH TOMATO VARIETY							
	DAY 0	DAY 5	DAY 10	MEANS	DAY 15	DAY 20	MEANS
BW	46.40	62.73	63.50	57.54d	63.03	58.24	60.64d
BWCS	50.70	63.98	69.77	61.48c	70.97	67.18	69.08a
CS	52.10	80.18	77.05	67.78b	75.80	67.03	71.42a
CTRL	54.70	89.06	75.78	73.18a			
SB	50.40	70.73	71.82	64.32c	70.23	61.74	65.99c
SBBW	48.50	60.23	65.74	58.16d	68.79	63.45	66.12c
SBCS	52.70	78.04	78.89	69.88b	74.38	68.80	71.59a
SBCSBW	51.00	70.98	74.98	65.65b	70.68	66.94	68.81b
Fpr.(0.05)	0.108	<0.01	0.081		0.08	<0.01	

Means sharing similar letters within columns are not significantly different from each other at LSD 0.05%.

1.9.1. EFFECT OF DIFFERENT WAXING MATERIAL ON THE EXTERNAL COLOUR OF POWER TOMATO VARIETY							
	DAY 0	DAY 5	DAY 10	MEANS	DAY 15	DAY 20	MEANS
BW	50.80	58.58	61.88	57.09d	62.01	65.20	63.61e
BWCS	55.70	64.72	68.42	62.95b	69.77	65.10	67.44c
CS	55.00	75.88	73.79	68.22b	73.38	62.87	68.12c
CTRL	58.20	89.89	75.48	74.52a			
SB	56.40	65.82	67.97	63.40b	68.81	59.37	64.09d
SBBW	54.40	62.79	65.66	60.95c	64.86	62.57	63.72e
SBCS	57.00	70.15	73.96	67.04b	76.01	67.87	71.94a
SBCSBW	55.20	68.87	71.02	65.03b	73.24	68.76	71.00b
Fpr.(0.05)	0.108	<0.01	0.081		0.08	<0.01	

Means sharing similar letters within columns are not significantly different from each other at LSD 0.05%.

APPENDIX 2Variate: **SHELFLIFE**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
WAX	7	1562.313	223.188	214.26	<.001
VARIETY	1	123.521	123.521	118.58	<.001
WAX.VARIETY	7	30.646	4.378	4.20	0.002
Residual	32	33.333	1.042		
Total	47	1749.812			

APPENDIX 3 SENSORY EVALUATION

Variate: ATTRACTIVENESS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
WAX	7			116.050	16.579	15.90 <.001
VARIETY	1			3.036	3.036	2.91 0.089
WAX.VARIETY	7			26.736	3.819	3.66 <.001
Residual	463	(1)		482.905	1.043	
Total	478	(1)		628.710		

Variate: FIRMNESS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
WAX	7			313.3698	44.7671	56.44 <.001
VARIETY	1			0.0812	0.0812	0.10 0.749
WAX.VARIETY	7			17.0646	2.4378	3.07 0.004
Residual	463	(1)		367.2103	0.7931	
Total	478	(1)		697.5407		

Variate: SKIN_COL

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
WAX	7			143.8094	20.5442	23.94 <.001
VARIETY	1			6.5575	6.5575	7.64 0.006
WAX.VARIETY	7			11.0933	1.5848	1.85 0.077
Residual	463	(1)		397.3897	0.8583	
Total	478	(1)		558.7390		

Variate: SMELL

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
WAX	7		162.1281	23.1612	30.14	<.001
VARIETY	1		2.9055	2.9055	3.78	0.052
WAX.VARIETY	7		11.8201	1.6886	2.20	0.033
Residual	463	(1)	355.7851	0.7684		
Total	478	(1)	532.5971			

Variate: OVER_ACC

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
WAX	7		142.3958	20.3423	31.88	<.001
VARIETY	1		0.8829	0.8829	1.38	0.240
WAX.VARIETY	7		21.5102	3.0729	4.82	<.001
Residual	463	(1)	295.4678	0.6382		
Total	478	(1)	460.1795			

APPENDIX 4: QUESTIONNAIRE

ASSESSMENT OF POSTHARVEST MANAGEMENT PRACTICES OF TOMATO IN FANTEAKWA DISTRICT.

SECTION A–DEMOGRAPHY (FARMERS ONLY)

Please tick [] where applicable

- Sex: Male [] Female []
- Age range: Below 18 years [] 18 – 24 years [] 25 – 40 [] 41 -55 years [] above 55 years []
- Marital status a) Married [] b) Single [] c) Widowed [] d) Divorced [] e) Separated []

EDUCATIONAL BACKGROUND

- What is your level of education? None [] Primary [] JHS/JSS [] Middle school [] Secondary [] Technical/ Vocational [] Certificate [] Diploma/ Degree [] other [] (Please specify).....
- How long have you been farming? Below 6yrs [] 6 – 10 yrs [] 10 – 15 yrs [] Above 16 yrs []
- How would you describe your farming activity? Subsistent [] Small scale [] Medium scale [] Large scale []
- What tomato variety / varieties do you cultivate? (a) Roma VF [] (b) Pectomech [] (c) Pectomech VF [] (d) Tropimech [] (e) Wosowoso, (f) Burkina [] (g) Ada Lorry Tyre [] (h) “No Name” (i) others specify.....

8. Is there any special reason(s) for your choice of variety? Yes [] / No []
9. If **yes**, can you share it/them with us?
.....
.....
10. What is the size of your farm?
11. Source of planting materials? a) Family [] b) Friends [] c) MOFA [] d) Others []
(Specify).....
12. Do you apply any agro-chemicals? a) Yes [] b) No []
13. What are the practices that affect post- harvest quality? Please specify
a) Land preparation [] b) Weeding [] c) Thinning [] d) Fertilizer and pesticide application []

HARVESTING AND POSTHARVEST PRACTICES

HARVESTING OPERATION

14. Do you prearrange for market before harvesting? Yes [] / No []
15. At what time of the day do you usually harvest your produce?
(a) Morning [] (b) Afternoon [] (c) Evening [] (d) No specific time []
16. Do you have any special reason for harvesting at a specific time of the day? Yes [] / No []
17. Does your reason have anything to do with the shelf life of the produce? Yes [] / No []
18. If yes, please explain?
19. At what stage of maturity do you harvest your produce?
(a) Mature unripe [] (b) Half ripe [] (c) Red ripe [] (d) other [] (Please specify).....
20. How do you harvest your fruit? (a) Manual [] (b) Mechanical []
21. If manual, please specify. a) By knife cutting [] b) by hand twisting []
22. Do you incur some losses during harvesting? a) Yes [] b) No []
23. If yes, what losses do you suffer? a) Mechanical [] b) Physiological [] c) Rotting []
24. What is the quantity of loss suffered? Please specify.....

LOSSES AT STORAGE AND STORAGE PRACTICES

25. Is there a ready market for your produce? Yes / No
26. Are you usually able to store your produce to prevent / reduce spoilage? Yes / No
27. If “Yes”, did you acquire this knowledge through a special training in storage? Yes / No
28. If yes, where did you get this special training?
 (a) School (b) Farmer’s forum (c) MoFA farmers’ field day (d) Traditional
 (e) Other (Please specify).....
29. How do you preserve your produce in case there is no ready market?
 (a) Stored in a specially conditioned storage facility (b) Freeze fresh (c) Boil and store
 (d) Convert into puree and store (e) None of the above/Poured on bare cemented floor
 (f) Others (Please specify)

30. Are you willing to adopt innovative storage methods if they prove more effective than what you currently use? Yes / No
31. What are the major challenges you face during storage?

32. Do you incur some losses during Storage? a) Yes b) No
33. If yes, what losses do you suffer? a) Mechanical b) physiological c) Rotting
34. What is the quantity of loss suffered? Please specify.....

LOSSES AT PACKAGING AND PACKAGING PRACTICES

36. What packaging material do you use for your produce? (a) Shallow wooden boxes
 (b) Long big wooden boxes (c) Plastic basket (d) cane basket (e) Other (please specify).....
37. Do you subject the produce to any special condition(s) before packaging them for market? Yes / No
38. If “Yes”, can you share it/them with us?

39. Do you incur some losses during Packaging? a) Yes b) No

40. What is the quantity of loss suffered? Please specify.....

41. What type of losses do you incur during packing?

a) Mechanical [] b) physiological [] c) Rotting []

POSTHARVEST LOSSES AND PRACTICES

41. What are the various causes of postharvest losses of tomato in your community?

(Tick as many as applicable)

a. Lack of market avenues [] b. Unreliable means of transport to move produce to market []

c. Lack of adequate storage facilities [] d. Lack of adequate storage technology []

e. Non-exposure to modern trends of tomato production [] f. Lack of processing plants []

g. Limited alternative uses of the produce [] i. Other [] (Please specify).....

42. Which of the following forms of losses do you incur? a. Bruises [] b. Rot [] c. theft [] d. Other [] (Please specify).....

FARMERS PERCEPTION ON WAXING OF TOMATO FRUIT AFTER HARVEST.

43. Do you know any modern storage technology of tomato fruit after harvest? Yes [] No.

44. Do you employ waxing in the preservation of your tomato fruits? (a)Yes [] (b) No []

45. If yes what are your reasons for using the waxing material in storage of the tomato fruit after harvest.

46. What type of waxing material do you use? (a) Sheabutter [] b) Paraffin wax oil [] c) Palm kernel oil [] d) Coconut oil [] e) Any other specify.....

47. Would you change your method of preservation if another method is proven to be more effective? a) Yes [] b) No []

SECTION B – QUESTIONNAIRE FOR TRADERS (WHOLESALE/RETAILERS)**DEMOGRAPHY (TRADERS ONLY)**

Please tick [] where applicable

1. Sex: Male [] Female []
2. Age range: Below 18 years [] 18 – 24 yrs [] 25 – 40yrs [] 41 -55 yrs [] above 55 yrs []
3. Marital status a) Married [] b) Single [] c) Widowed [] d) Divorced [] e) Separated []

EDUCATIONAL BACKGROUND

4. What is your level of education? None [] Primary [] JHS/JSS [] Middle school [] Secondary [] Technical/ Vocational [] Certificate [] Diploma/ Degree [] other [] (Please specify).....
5. How long have you been trading in tomatoes? (a) Below 1 year [] (b) 1 – 4 years [] (c) 5 – 8 years [] (d) Over 8 years []
6. What variety(s) of tomato do you trade in? (a) Roma VF [] (b) Pectomech [] (c) Pectomech VF [] (d) Tropimech [] (e) Wosowoso, (f) Burkina [] (g) Ada Lorry Tyre [] (h) “No Name” (i) others specify.....
7. Do you have any reason for your choice(s)? Yes [] / No []
8. Can you share them with us?
 - a
 - b.....
8. Have you ever experienced a great loss of your goods through spoilage? Yes [] / No []
9. How would you assess the rate of tomato spoilage in your area over the years?
 - a) Very high [] b) High [] c) Low [] d) Very low [] e) Stable [] f) Reducing []
10. Which of the following accounts for the losses? (a) Lack of ready market [] (b) Lack of transport of produce [] (c) Lack of storage facility [] (d) Lack of storage technology [] (e) Pest attack [] (f) others [] (Please specify.....
11. How do you usually transport purchased produce to your point of sale?
 - a) By vehicle [] b) By any available head-loaded porter [] c) Any other [].....
12. What type of vehicle do you use to transport your produce?
 - a) Open truck [] b) Van or roofed truck [] c) Other [] Please specify:

12. Do you incur commodity losses from the point of purchase to the point of sale?
a) Yes [] b) No []
13. If “yes”, what losses do you suffer? a) Quantitative loss [] b) Qualitative loss
14. What is the quantity of loss suffered? Please specify.....
16. Are you often able to prolong the shelf life of your goods? Yes [] / No []
17. If “Yes”, did you learn this skill from a special training? Yes [] / No []
18. From which organization did you get this training? (a) Traders association [] (b) MoFA staff [] (c) NGO [] (d) Others [] Please specify).....

TRADERS PERCEPTION ON WAXING OF TOMATO FRUIT AFTER PURCHASING.

19. Do you know any effective modern storage technology of tomato fruit that can extend its shelf life and improve its quality? a) Yes [] b) No []
20. Do you employ waxing in the storage of your tomato fruits? (a)Yes. [] (b) No []
21. If “Yes” what are your reasons for using the waxing material in storage of the tomato fruit after harvest.
a.
b.
c.
22. What type of waxing material do you use? a) Sheabutter [] b) Paraffin wax oil [] c) Palm kernel oil [] d) Coconut oil [] e) Any other specify.....
25. Would you change your method of preservation if another method is proven to be more effective? a) Yes [] b) No []

TRANSPORTATION LOSSES.

26. In your opinion how would you rate the condition of your vehicle in transporting the goods?
a) Very good [] b) Good [] c) Average [] d) Bad [] e) Very bad []
27. In your own assessment, what is the condition of the road network that you use on during the rainy season? a) Very good [] b) Good [] c) Average [] d) Bad [] e) Very bad []
28. Do you suffer losses? a) Yes [] b) No []
29. If yes, what type of losses do you suffer? a) Quantitative loss [] b) Qualitative loss []

30. What quantity of loss do you suffered? Specify.....

31. In your opinion where do you think most of the losses occur from the point of purchase to the point of sale?

QUESTIONNAIRE FOR CONSUMERS ONLY

DEMOGRAPHY (CONSUMERS ONLY)

Please tick [] where applicable

1. Sex: Male [] Female []

2. Age range: Below 18 yrs [] 18 – 24 yrs [] 25 – 40 yrs [] 41 -55 yrs [] above 55 yrs []

3. Marital status a) Married [] b) Single [] c) Widowed [] d) Divorced [] e) Separated []

EDUCATIONAL BACKGROUND

4. What is your level of education? None [] Primary [] JHS/JSS [] Middle school [] Secondary [] Technical/ Vocational [] Certificate [] Diploma/ Degree [] other [] (Please specify).....

5. Do you eat tomato? Yes [] No []

6. How often do you take tomato? At least once daily [] At least twice daily [] In most meals [] Not often []

7. At what stage of maturity do you usually consume tomatoes? Red ripe [] Half ripe [] Mature unripe (green) [] Immature [] All of the above []

8. What qualities do you look for when purchasing tomatoes from the market?

Firmness and Colour [] weight [] Freshness and Appearance [] others specify.....

9. How do you store your tomato fruits when there is excess.....

10. Do you know any effective modern storage technology of tomato fruit that can extend its shelf life and improve its quality? a) Yes [] b) No []

11. If yes can you share them with us?.....

12. Would you like to buy tomatoes that have been waxed to improve its quality? Yes [] No []