

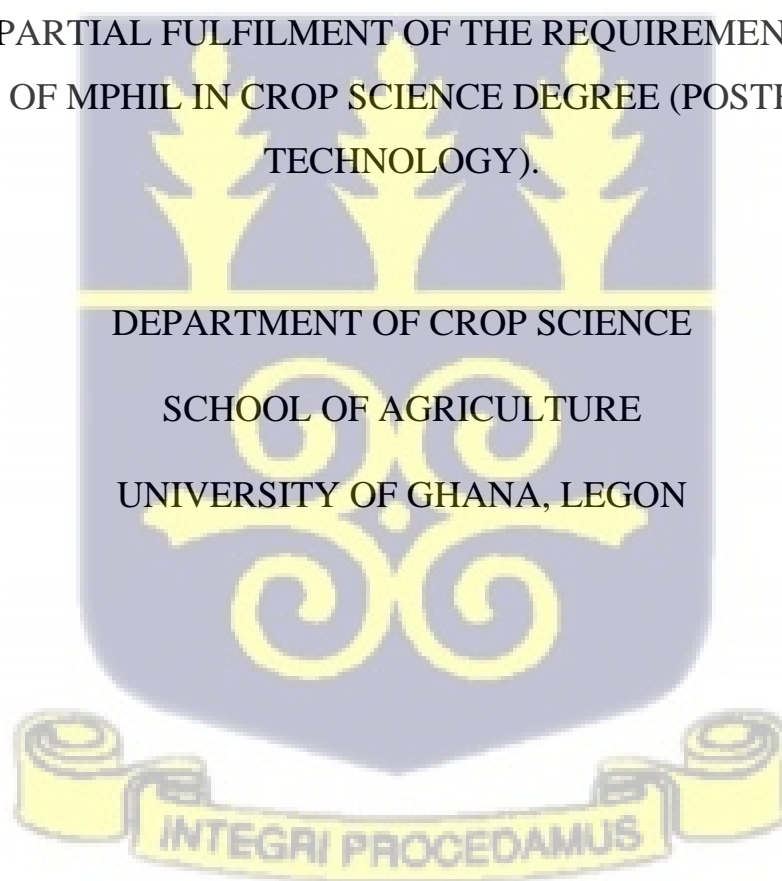
EFFECT OF DIFFERENT EDIBLE COATINGS ON QUALITY OF TOMATOES (*Solanum Lycopersicum*) STORED AT DIFFERENT TEMPERATURES.

BY

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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA,
LEGON IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
AWARD OF MPhil IN CROP SCIENCE DEGREE (POSTHARVEST
TECHNOLOGY).



2022

DECLARATION

I, hereby declare that, except the 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.



13 October 2023

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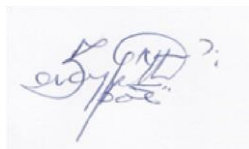
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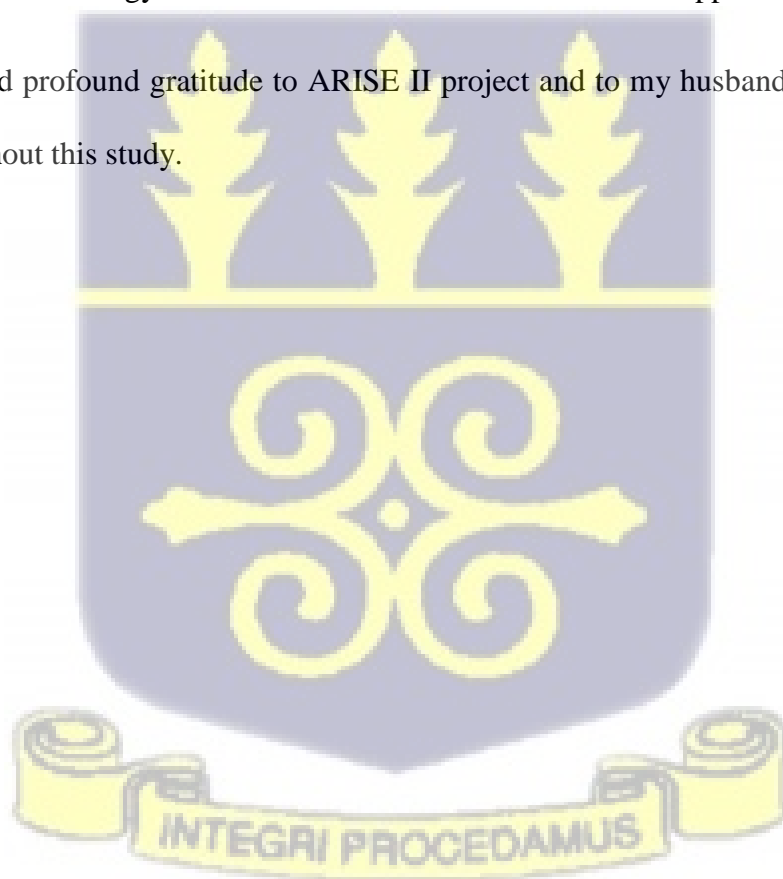
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LIST OF ABBREVIATION

CS- Cassava starch

CA- Citric Acid

CS:CA- Cassava starch and Citric Acid

P: Pectomech variety of tomato

W: Wosowoso variety of tomato

FAO: Food and Agriculture Organization

FAOSTAT: Food and Agriculture Organization Statistics

U.S.: United State

PH: Potential of hydrogen

TA: Titratable acidity

NAOH: Sodium hydroxide

TSS: Total soluble solid

FASDEP: Food and Agricultural Sector Development Policy document



ABSTRACT

This study was conducted to determine the effect of different edible coatings, packaging materials on shelf-life and quality of two varieties of tomatoes (Pectomech and wosowoso). Due to its perishability, tomato is associated with many postharvest loss issues which can be attributed to lack of good management practices (use of poor varieties, packaging and improper storage) which result in poor quality and short shelf-life.

The study, was conducted using two tomato varieties (Pectomech and wosowoso), baskets and polyethylene bags were used as packaging materials, edible coatings such as cassava starch (CS), citric acid (CA) and their mixture were used to apply the coatings on two varieties of tomatoes before their storage at different temperatures (4°C and 28°C).

The treatments used were two varieties of tomatoes (Pectomech and wosowoso), three edible coatings with different concentrations: **1.** Cassava starch (1%, 2%, 3%); **2.** Citric acid (0.5%, 1%); **3.** Cassava starch + Citric acid (1:0.5; 1:1; 2:0.5; 2:1; 3:0.5, 3:1); two method of applications (Dipping and brushing), two packaging materials, two storage temperatures (28°C, 4°C) and control.

The results indicated that the coating material in maintaining quality of pectomech tomatoes was the samples dipped in cassava starch mixed with citric acid at a ratio of 3:1 (3:1 CS+CA, dipping). The shelf life of pectomech tomatoes was longer than shelf life of wosowoso in all treatments and the shelf life in refrigeration storage was longer than room storage for both varieties. Polyethylene packaging was better than control and basket in terms of weight loss, lycopene, pH, TA and vitamin c during 21 days of storage. Considering all the sensory attributes, for the two varieties of tomatoes, consumers preferred tomato fruits packed in polyethylene packaging material.

Farmers and traders should be encouraged to apply edible coatings such as cassava starch and citric acid to coat tomatoes at right coating concentration (3:1 CS+CA, dipping) before packing them in polyethylene bags and at room temperature respectively.

Key words: Tomatoes, edible coating, storage temperature, packaging materials

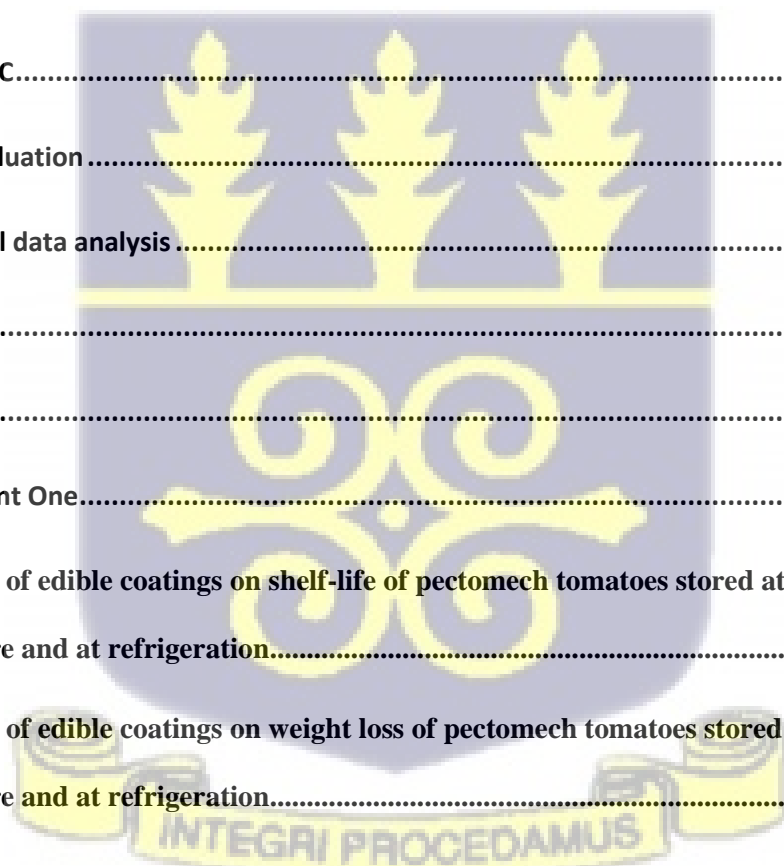


TABLE OF CONTENTS

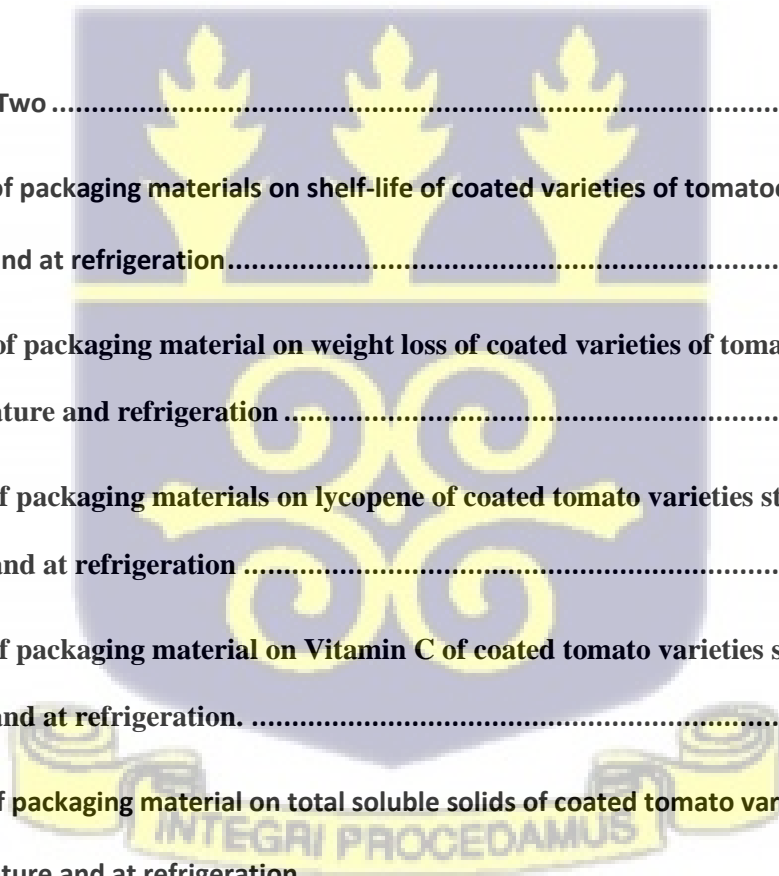
DECLARATION.....	ii
ACKNOWLEDGEMENTS	iii
LIST OF ABBREVIATION	iv
ABSTRACT.....	v
TABLE OF CONTENTS.....	vii
LIST OF TABLES	xiii
CHAPTER ONE: INTRODUCTION.....	1
1.1. Background of the study.....	1
1.2 Problem statement.....	3
1.3 Justification	3
1.4 Objectives.....	5
1.4.1 Main objective.....	5
1.4.2 Specific objectives	5
CHAPTER TWO: LITERATURE REVIEW.....	6
2.1 History of tomato.....	6
2.2 Health benefits of tomatoes.....	6
2.3 Production of tomatoes	7
2.4 Tomato production in Ghana	7
2.5 Postharvest losses	10

2.6 Preservation methods	11
2.6.1 Drying	12
2.6.2 Edible coatings	13
2.6.3 Packaging materials	16
2.7 Nutritional value	17
2.8 Quality indices of tomato (physical chemical properties)	17
2.8.1 The weight of tomato	18
2.8.2 Potential of hydrogen (pH)	18
2.8.3. Titratable acidity (TA)	19
2.8.4 Total Soluble Solid (TSS)	19
2.8.5 Lycopene	20
2.8.6. Fruit firmness	21
2.8.7 Shelf life	21
2.8.8 Vitamin c (Vit. c)	22
CHAPTER THREE: MATERIALS AND METHODS	23
3.1 Collection of samples	23
3.2. Preparation of samples and coating materials	24
3.2.1. Tomatoes	24
3.2.2. Coating materials	24
3.2.2.1 Cassava starch	24
3.2.2.2 Citric acid	25
3.2.2.3 Cassava starch and citric acid combination	25

3.3. Coating of tomatoes	25
3.4. Determination of physicochemical properties of coated tomatoes.....	27
3.4.1. Shelf- life	27
3.4.2. Weight loss.....	27
3.4.3 Firmness.....	28
3.4.4 Total soluble solids (TSS)	28
3.4.5 Potential of hydrogen (pH).....	29
3.4.6 Titratable acidity (TA)	29
3.4.7 Lycopene	30
3.4.8 Vitamin C.....	30
3.5. Sensory evaluation.....	31
3.6. Statistical data analysis	31
CHAPTER FOUR.....	32
4.0. RESULTS.....	32
4.1. Experiment One.....	32
4.1.1 Effect of edible coatings on shelf-life of pectomech tomatoes stored at room temperature and at refrigeration.....	32
4.1.2 Effect of edible coatings on weight loss of pectomech tomatoes stored at room temperature and at refrigeration.....	34
4.1.3: Effect of edible coatings on the total soluble solid (TSS) of pectomech tomatoes stored at room temperature and at refrigeration.	36



4.1.4 Effect of edible coatings on firmness of pectomech tomatoes stored at room temperature and at refrigeration.....	39
4.1.5. Effect of edible coatings on the lycopene of pectomech tomatoes stored at room temperature and at refrigeration.....	43
4.1.6 Effect of edible coatings on potential of Hydrogen (pH) of tomatoes stored at room temperature and at refrigeration.....	45
4.1.7. Effect of edible coatings on the Vitamin c of tomatoes stored at room temperature and refrigeration.	48
4.1.8. Effect of edible coatings on titratable acidity (TA) of tomatoes stored at room temperature and refrigeration.....	51
4.2. Experiment Two	54
4.2.1. Effects of packaging materials on shelf-life of coated varieties of tomatoes stored at room temperature and at refrigeration.....	55
4.2.2. Effects of packaging material on weight loss of coated varieties of tomatoes stored at room temperature and refrigeration	56
4.2.3 Effects of packaging materials on lycopene of coated tomato varieties stored at room temperature and at refrigeration	58
4.2.4 Effects of packaging material on Vitamin C of coated tomato varieties stored at room temperature and at refrigeration.	59
4.2.5 Effects of packaging material on total soluble solids of coated tomato varieties stored at room temperature and at refrigeration.....	61
4.2.6 Effects of packaging material on potential of Hydrogen (pH) of coated tomato varieties stored at room temperature and at refrigeration.	63



4.2.7 Effects of packaging material on titratable acidity (TA) of coated tomato varieties stored at room temperature and at refrigeration.....	64
4.3 Sensory evaluation of tomato varieties following different packaging materials and storage places.	66
CHAPTER FIVE.....	69
5.0 DISCUSSION.....	69
5.1 Effect of edible coatings on shelf-life of tomatoes stored at room temperature and at refrigeration.....	69
5.2. Effect of edible coatings on weight loss of pectomech tomatoes stored at room temperature and at refrigeration.	70
5.3. Effect of edible coatings on the total soluble solid (TSS) of pectomech tomatoes stored at refrigeration and at room temperature	71
5.4. Effect of edible coatings on firmness of pectomech tomatoes stored at refrigeration and at room temperature	72
5.5. Effect of edible coatings on lycopene of pectomech tomatoes stored at refrigeration and at room temperature	73
5.6. Effect of edible coatings on potential of Hydrogen (pH) of pectomech tomatoes stored at refrigeration and at room temperature	74
5.7. Effect of edible coatings on Vitamin C of pectomech tomatoes stored at refrigeration and at room temperature	75
5.8. Effect of edible coatings on titratable acidity (TA) of pectomech tomatoes stored at refrigeration and at room temperature	76
5.9. Effect of packaging materials on shelf life of pectomech and wosowoso varieties of tomatoes stored at refrigeration and at room temperature.....	77

5.10. Effect of packaging materials on weight loss of tomatoes varieties stored at refrigeration and at room temperature. 78

5.11 Effect of packaging materials on lycopene value of varieties of tomatoes stored at refrigeration and at room temperature 79

5. 12. Effect of packaging materials on Vitamin c value of tomatoes varieties stored at refrigeration and at room temperature 80

5. 13. Effect of packaging materials on total soluble solid (TSS) value of varieties of tomatoes stored at refrigeration and at room temperature 81

5. 14. Effects of packaging material on potential Hydrogen value (pH) of coated tomato varieties stored at room temperature and at refrigeration temperature. 82

5. 15. Effects of packaging material on titratable acidity (TA) of coated tomato varieties stored at room temperature and at refrigeration temperature. 82

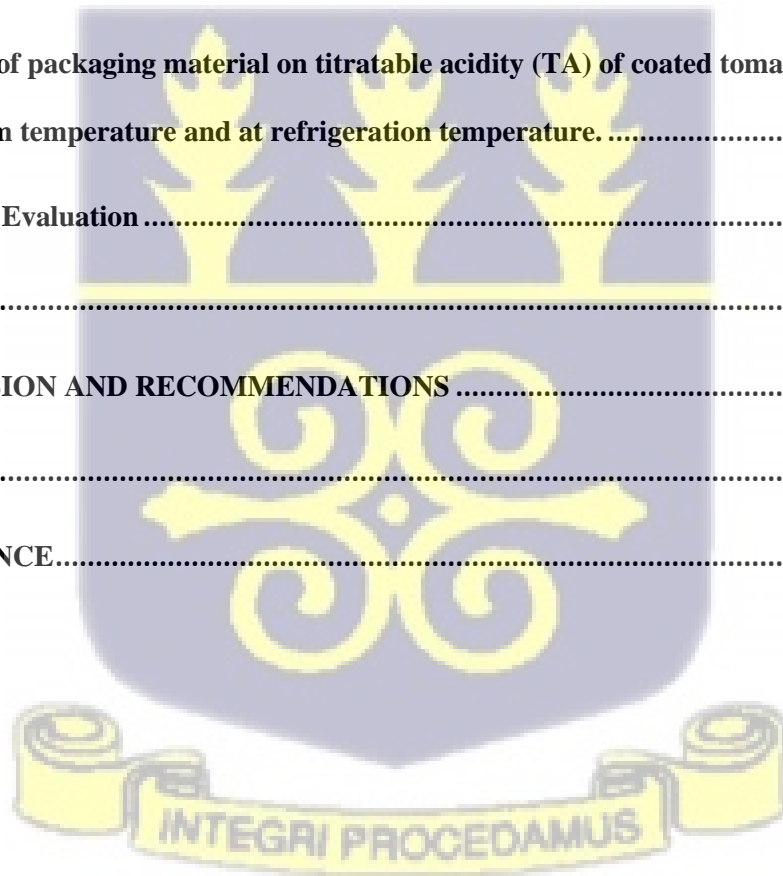
5.16. Sensory Evaluation 83

CHAPTER SIX..... 84

6. CONCLUSION AND RECOMMENDATIONS 84

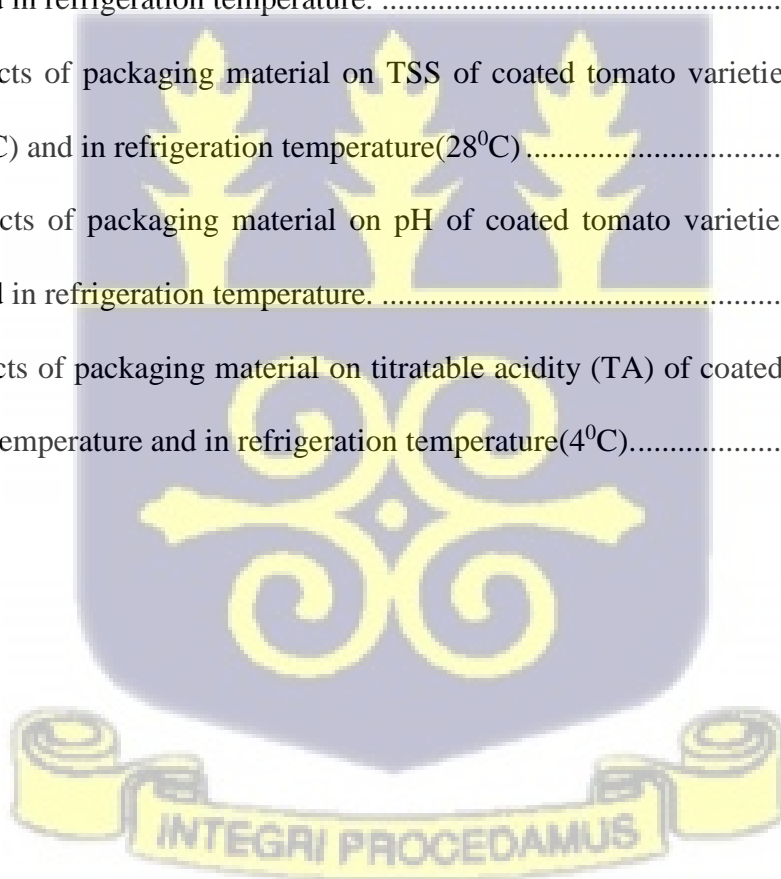
CHAPTER SEVEN..... 88

7.1 REFERENCE..... 88



LIST OF TABLES

Table 3.1 DESCRIPTION OF MATERIALS AND TREATMENTS RATIOS.....	25
Table 4.1: Changes in TSS according to different coating materials.	38
Table 4.2: Changes in firmness according to different coating materials.....	42
Table 4.3: Effect of edible coatings on the pH of tomatoes stored at room temperature (28 ⁰ C) and at refrigeration (4 ⁰ C)	Error! Bookmark not defined.
Table 4.4: Effect of edible coatings on the Titratable acidity (TA) of tomatoes stored at room temperature and in refrigeration temperature	53
Table 4.5: Effects of packaging material on lycopene of coated tomato varieties stored at room temperature and in refrigeration temperature.	59
Table 4.6: Effects of packaging material on TSS of coated tomato varieties stored at room temperature(4 ⁰ C) and in refrigeration temperature(28 ⁰ C)	62
Table 4.7: Effects of packaging material on pH of coated tomato varieties stored at room temperature and in refrigeration temperature.	64
Table 4.8: Effects of packaging material on titratable acidity (TA) of coated tomato varieties stored at room temperature and in refrigeration temperature(4 ⁰ C).....	65



LIST OF FIGURES

Figure 3.1: Laboratory scale used by measuring the weights of tomatoes every two days.27

Figure 3.2: The pH meter used for measuring the pH of tomatoes.....29

Figure 4.1: Effect of edible coatings on shelf life of tomatoes stored at room temperature (28° C) and in refrigeration (4°C) with dipping method.....33

Figure 4.2 Effect of edible coatings on shelf-life of tomatoes stored at room temperature (28°C) and in refrigeration (4°C) with brushing method.....33

Figure 4.3: Effect of edible coatings on weight loss of tomatoes stored at room temperature (28°C) and in refrigeration (4°C) with dipping method.35

Figure 4.4: Effect of edible coatings on weight loss of tomatoes stored at room temperature (28°C) and in refrigeration (4°C) with brushing method.36

Figure 4.5: Effect of edible coatings on lycopene of tomatoes stored at room temperature (28°C) and in refrigeration (4°C) with dipping method.....44

Figure 4.6: Effect of edible coatings on lycopene of tomatoes stored at room temperature (28°C) and in refrigeration (4°C) with brushing method.....45

Figure 4.7: Effect of edible coatings on vit. c of tomatoes stored at room temperature (28°C) and in refrigeration (4°C) with brushing method.....50

Figure 4.8: Effect of edible coatings on vit. c of tomatoes stored at room temperature (28°C) and in refrigeration (4°C) with brushing method.....51

Figure 4.9: Effects of packaging material on shelf-life of coated tomato varieties (pectomech and wosowoso) stored at room temperature(28°C) and in refrigeration temperature(4°C).56

Figure 4.10: Effects of packaging material on weight loss of coated tomato varieties stored at room temperature and in refrigeration temperature; Rt: Room temperature(28°C); Rft: refrigeration temperature(4°C).....57

Figure 4.11: Effects of packaging material on Vit C of coated tomato varieties stored at room temperature and in refrigeration temperature(4⁰C).....61

Figure 4.12: The sensory evaluation of pectomech and wosowoso tomatoes packed in room(28⁰C) and refrigeration temperature(4⁰C).....68

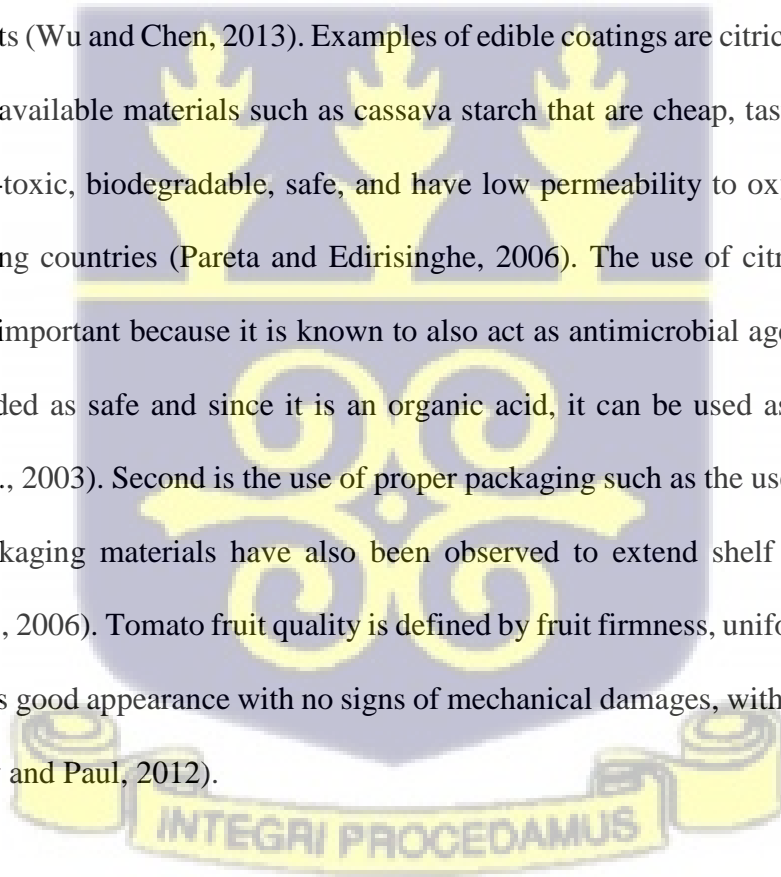


CHAPTER ONE: INTRODUCTION

1.1. Background of the study

Tomato (*Solanum lycopersicum*) is a major horticultural crop and climacteric fruit that continues to ripen after harvesting (Zapata et al., 2008). It is one of the most widely consumed vegetables worldwide and it contains significant amounts of vitamin C and lycopene (Chapagain and Wiesman, 2004). Vitamin C is anti-oxidant, which reduces the risk of arteriosclerosis, cardiovascular diseases and some form of cancer. Tomatoes (*Solanum lycopersicum*) is a good source of minerals and vitamins (Nasrin et al., 2008, & Babalola et al., 2010) and it is also known to be a major source of antioxidants; hence consumption of tomato/tomato products may help reduce the risk of cancer and cardiovascular diseases (Giovannucci et al., 2002). Lycopene is an antioxidant found in tomato and it is responsible for the red colour in tomatoes (Borguini and Ferraz, 2009; Kotikova et al., 2011; Vallverdu-Queralt et al., 2011). Tomato is a vegetable of high economic importance in many countries (Obeng-Ofori, et al., 2007). Postharvest losses have been highlighted as one of the determinants of the food problem in most developing countries (Babalola et al., 2008). According to Gil et al., (2006), loss of nutritional quality in tomato fruits can be observed depending on storage conditions. Post-harvest loss of tomatoes is mostly caused by decay and external injury during handling and storage. According to Salami et al. (2010), about 30-40% of fruits and vegetables are lost or discarded after leaving the farm gate. The Shelf life is the period in which a product can continue to survive without deterioration or other changes during storage. The Shelf-life is a function of time, environmental factors, and susceptibility of product to quality change (Labuza and Szybist, 2001). One of the factors that is known to affect shelf-life and quality of tomatoes during storage is the temperature (Bachmann and Earles, 2000). Fully ripe tomato

fruits can be stored at 2 – 5 °C to avoid chilling injury (Passam et al., 2007). As tomato is a climacteric and perishable produce, good and protective methods are required to increase their self-life and physical qualities (Saeed et al., 2010). One of the good protective methods that can be used, is the use of edible coatings which are thin layers of material applied to edible food products play an important role in the preservation of the foods (Falguera et al., 2011). The use of edible coatings with low-temperature storage minimizes deterioration of tomatoes (Gonzalez-Agilar et al., 2010). Edible coatings have been used for extension of postharvest storage time of fruits and vegetables (Allegra et al. 2016; Raffo et al. 2002; Singh et al. 2016). Coatings forms a semipermeable barrier around fruits, reduce solute migration, gas exchange, moisture evaporation, respiration and oxidative reaction rates and suppress physiological disorders in fruits (Wu and Chen, 2013). Examples of edible coatings are citric acid and cassava starch. Locally available materials such as cassava starch that are cheap, tasteless, odourless, colourless, non-toxic, biodegradable, safe, and have low permeability to oxygen are best for use in developing countries (Pareta and Edirisinghe, 2006). The use of citric acid as edible coating is very important because it is known to also act as antimicrobial agent. Citric acid is generally regarded as safe and since it is an organic acid, it can be used as a food additive (Sommers, et al., 2003). Second is the use of proper packaging such as the use of polyethylene and plastic packaging materials have also been observed to extend shelf life of tomatoes (Srinivasa, et al., 2006). Tomato fruit quality is defined by fruit firmness, uniformity and glossy colour as well as good appearance with no signs of mechanical damages, withering and bruises (Chattopadhyay and Paul, 2012).



1.2 Problem statement

The shelf life of tomatoes is relatively short due to different postharvest physiological, physical and chemical changes that occur during storage (Fagundes, et al., 2015; Hoerberichts, et al., 2002). Quality of most fruits and vegetables is affected by water loss during storage, which depends on the temperature and relative humidity conditions (Perez et al., 2003). Major losses in the quality and quantity of fresh vegetable and fruit products occur between harvest and consumption (Brooks, et al., 2008). Post-harvest loss of tomatoes is mostly caused by decay and external injury when they are handling and storing them. The nutritional quality of fresh tomatoes has been determined to be affected by postharvest activities such as handling and storage practices (Addo, et al., 2015). Postharvest qualitative loss in tomato can have a negative impact on many parameters like consumer acceptability and nutrient value of fruits. Tomato being a climacteric fruit has a relatively short postharvest life. The major factor associated with tomato postharvest shelf life is increased respiration that results in high fruit ripening and deterioration of tomato quality (Bailén, et al., 2006).

Therefore, this study was aimed at determining the effect of different edible coatings with various packaging materials on shelf-life and quality of tomatoes stored under different conditions.

1.3 Justification

As tomato is a climacteric fruit and as such continues to ripen even after harvest, it tends to have a rather short shelf-life. Deterioration of tomato quality during storage is a serious post-harvest problem for traders and consumers. Thus, the requirement of technology development to reduce post-harvest losses and extending shelf-life of tomatoes is needed (Gonzalez-Aguilar, et al., 2009). The development of different preservation technologies is required to

avoid losses and deterioration of tomatoes. Good and protective storage methods are required to enhance their shelf life as well as their physical qualities (Saeed, et al., 2010). Edible coatings have been used for extension of self-life of fruits and vegetables (Allegra, et al., 2016; Raffo, et al., 2002; Singh, et al., 2016). The use of citric acid and cassava starch in this study, is because cassava starch is cheap, tasteless, odourless, colourless, non-toxic, biodegradable, safe, and have low permeability to oxygen (Pareta and Edirisinghe, 2006). Citric acid is cheap, easily obtained and safe for consumption. Citric acid also acts as antimicrobial agent on different products. Since bacteria are unable to grow in an acidic environment, citric acid is often added to different agricultural products as a form of preservation. The edible coatings can reduce moisture loss, solutes migration, respiration and oxidative reaction rates (Colla, Sobral and Menegalli, 2006; Rojas-Graü, et al., 2008). However, there is little information available in literature about the application of edible coatings on fruits (González-Aguilar, et al., 2008; Sothornvit and Rodsamran, 2010). Cassava starch and citric acid were used in this study as edible coatings because edible coating is one of the modified atmosphere methods that have shown promising results for preserving fruits quality (Guimaraes, et al., 2018). An ideal edible coating can provide a partial barrier to water movement that can reduce moisture loss from the fruit surface and modify the atmosphere around the fruit by acting as a barrier to gas exchange (Jongsri, et al., 2016). Cassava starch edible coating is tasteless, odourless, colourless, non-toxic, biodegradable, cheap, safe, and shows low permeability to oxygen (Pareta and Edirisinghe, 2006; Chiumarelli, et al., 2010). The use of citric acid can avoid enzymatic browning of plant tissue, thereby reducing the product appearance loss, without changing its minimally processed condition (Andrés, Giannuzzi, and Zaritzky, 2002; Brennan, Le Port and GormLey, 2000; Moda, et al., 2005). Therefore, this study will focus on the use of edible coatings applications on tomato to extend their shelf life and conserve their quality.

1.4 Objectives

1.4.1 Main objective

The main objective of this study was to determine the effectiveness of different edible coatings in extending the shelf life and quality of tomatoes.

1.4.2 Specific objectives

1. To determine the optimum concentration of coating materials to be applied on tomatoes.
2. To determine the combined effects of temperature and packaging material on the physicochemical properties and shelf life of coated tomatoes.
3. To determine consumer acceptability of tomato coated with different edible coatings.



CHAPTER TWO: LITERATURE REVIEW

2.1 History of tomato

Tomato (*Solanum lycopersicum*) has its origin in South American Andes (Naika et al., 2005) which is Peru of today. It was taken to other parts of the world by explorers where it was used for ornamental purpose but not eaten because they took it as poisonous. They were accepted it as edible crop in Europe in 1840 (Paran and Van der Knaap, 2007). Today different benefits of tomato are known where it is consumed wherever in different recipes.

2.2 Health benefits of tomatoes

Tomato serves as a medicine crop. Consumption of fruits and vegetables is linked to the lower risk of several types of cancer. Tomatoes contains higher amounts of lycopene, a type of carotenoid with anti-oxidant properties (Arab and Steck, 2000) which is beneficial in reducing the incidence of some chronic diseases (Basu and Imrhan, 2007) like cancer and many other cardiovascular disorders (Freeman and Reimers, 2010). Lycopene is believed to be the main contributing compound in tomatoes responsible for lower risk of prostate cancer (Pohar, et al., 2003). Lycopene in tomatoes enhance fertility by improving the quality and swimming speed of sperm while reducing the number of abnormal sperm in men (Innes 2014). Consumption of tomatoes can prevent old-age related diseases like dementia, osteoporosis, Parkinson's and Alzheimer's (Freeman and Reimers, 2010). Tomatoes have high sources of vitamin C which is used in cell division and cell wall synthesis (Gest, et al., 2012). Ascorbic acid is an important micronutrient and antioxidant for human diet.

2.3 Production of tomatoes

Tomato production is a source of income in all areas of the world. Although there are more benefits from tomatoes, its production is not enough due to postharvest losses. Global tomato production increased during the 1920s as a result of breakthroughs in technologies that made mechanised processing possible (Tan, et al. 2010). According to different series of genetic research findings, tomato is from the solanum genus. Tomato is an herbaceous perennial, but according to different growing environmental conditions they can behave as annuals (Denham, 2014). A large produced quantity of tomatoes is processed in different final products such as tomato ketchup, tomato paste, canned tomatoes, sun-dried tomatoes, etc. Some tomato varieties that can be produced are Pectomech, Wosowoso, Tropimech, Laurano etc. The pectomech variety is the most suitable for processing (Robinson and Kolavalli, 2010). The low productivity of tomato is due to different reasons such as short shelf life, season of production, lack of rapid market access, and lack of sales for farmers leading to financial losses (Robinson and Kolavalli, 2010). Tomato production accounts for about 4.8 million hectares of harvested land area globally with an estimated production of 162 million tonnes (FAOSTAT, 2014).

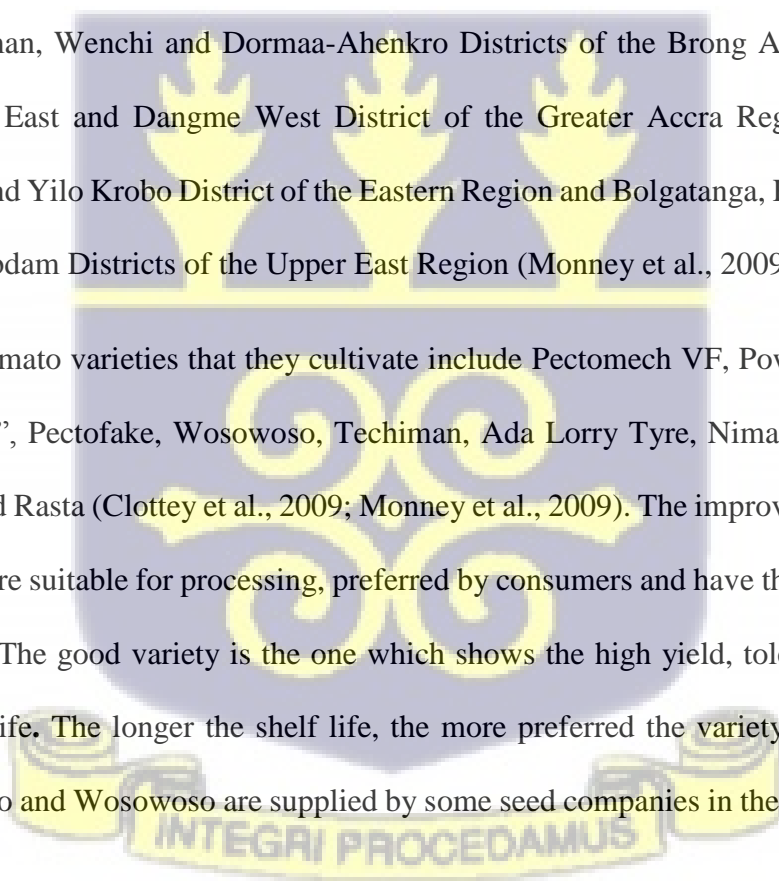
2.4 Tomato production in Ghana

Tomato is very important component in Ghana as cash crop and in diets. Tomato cultivation has been one of the most important income-generating vegetables produced in Ghana (Asante, et al., 2013). The production of tomato is concentrated in the Greater Accra, Ashanti, Brong Ahafo, Volta and Upper East regions under both rain-fed and irrigated systems. Its production in Ghana seems to have declined while the increase of tomato paste imports since 2000s is very high. The low productivity and high prices put pressure on domestic processing and domestic

agriculture (Wilkinson and Rocha, 2006). Ghana demand high imported paste than domestic fresh tomato due to the low efforts in processing tomato domestically. The trade of fresh tomato is limited with some closed neighbours of Ghana such as (Burkinafaso, Cote d'Ivoire, and Togo). Farmers like production of tomato than other vegetables due to its high multiple harvests, which bring high benefits per unit area. Tomato is characterised by its shape, size, colour, fresh thickness, number of locules and fruit quality which differ in acceptability, quality and storability in the local area. The Food and Agricultural Sector Development Policy document of Ghana (FASDEP) reported that post-harvest losses are high due to very little processing and strategies in marketing (2007). Since the country's consumption of tomato is increasing, tomato has to be stored and transported very well at various distances to consumers. Inappropriate methods of Packing, transportation and storage result in deterioration of tomatoes. For the case study of Ghana, the available data suggests that Ghana imports 100 thousand tonnes per year of tomatoes from Burkinafaso (OCED Headquarters, Paris; 2010). The perishability of tomato increases the post-harvest losses which force farmers to accept low prices. Boriss and Brunke (2005) reported that the price of tomato depends on availability and shortage of supply. In Ghana's tomato sector, production seasonality, the dominance of rainfed agriculture, high perishability of the fruits combined with no storage facilities, and poor market access, have resulted in low average yields due to high spoilage. The low price of tomatoes in Ghana is due to their high perishability (Bell, et al., 1999; Orchard and Suglo, 1999). In Ghana the packaging of tomatoes is done by using oversized crates after removing the poorest fruit qualities and varieties. In late December through April/May Ghana's Upper East region and Burkina Faso supply almost all the fresh tomato in the country. Irrigated tomato from Greater Accra dominates the market later in the year. Even Ghana relies on tomato from Burkinafaso, there are three large-scale tomato processors in Ghana that, when functioning, provide an additional market for tomato farmers: Wenchi in Brong Ahafo; Northern Star (formerly named

Pwalugu) in Upper East; and Expom (formerly named Trusty Foods) in Greater Accra (Robinson and Kolavalli, 2010). The yield of tomato in Ghana, is lower than 10 t/ha and is not enough like other African countries (Robinson, et al., 2010b). This yield of tomatoes is slightly above 10 t/ha from 1970 and 1980 but are lower than the estimates reported by Wolff (1999). Due to this low yield Ghana is a net importer of fresh tomato fruits from neighbouring countries like Burkina Faso and Ivory Coast in the dry seasons and processed tomato products, mainly canned tomato pastes from China and Italy (Monney, et al., 2009; Horna, et al., 2006). The import of processed tomato in Ghana from the EU increased by 628% from 3,713 tons to 27,015 tons between 1993 and 2003 (Donkor, et al., 2013). Tomato is produced in the whole parts of the country of Ghana such as Akomadan and Afrancho of the Offinso District of the Ashanti Region; Techiman, Wenchi and Dormaa-Ahenkro Districts of the Brong Ahafo Region; Ga West, Dangme East and Dangme West District of the Greater Accra Region; Fanteakwa, Kwahu South and Yilo Krobo District of the Eastern Region and Bolgatanga, Kasena Nankana and Talensi Nabdam Districts of the Upper East Region (Monney et al., 2009).

The different tomato varieties that they cultivate include Pectomech VF, Power Rano, Heinz, Paul, “five-five”, Pectofake, Wosowoso, Techiman, Ada Lorry Tyre, Nimagent F1, Deca 1, Meenagiant, and Rasta (Clotey et al., 2009; Monney et al., 2009). The improved varieties such as pectomech, are suitable for processing, preferred by consumers and have the high price than other varieties. The good variety is the one which shows the high yield, tolerate disease and has long shelf-life. The longer the shelf life, the more preferred the variety (Monney et al., 2009). Navrongo and Wosowoso are supplied by some seed companies in the nation of Ghana.



2.5 Postharvest losses

Tomato is a vegetable which is highly perishable, spoiling within 4 to 6 days after harvest depending on the variety leading to huge economic losses to growers (Ellis et al., 1998). After harvesting loss is known as a quantitative and qualitative loss of a product along the post-harvest chain (DeLucia and Assennato, 1994). It is the change in food availability, edibility and quality that reduce its consumption (FAO and UNEP, 1981). The reason for that loss, is the proximity of processing facilities to farms and inaccessibility to markets are major post-harvest challenges (GOG, 2003). The main factors of losses in tomato post-harvest, is the adoption of poor varieties with low shelf-life, harvesting at improper stage, improper care at harvest, packaging in bulk without sorting and grading of tomatoes, improper transportation and storage which result in pathogenic infestation and long periods of market distribution (Adubofour et al., 2010; Mujibur Rehman et al., 2007; Ellis et al., 1998). Literacy is the factor which comes in farmer's decision adoption of new technologies. Thus, to adopt new technologies and innovations, they need some education. The other challenge they have is that, most farmers are not land owners but are rather tenants (Mujibur Rehman et al., 2007). Therefore, the result is the non-improved productivity because farmers don't like to invest at long term thinking that they are tenants. The skilled labour plays an important role in post-harvest losses where they pick and handle the produce with good care and little damage. The non-skilled labourers must work under the supervision of the farmers who hire them (Mujibur Rehman et al., 2007). When tomatoes are red ripe it is the time for harvesting which is done two or three times a week, according to the variety and yield (Monney et al., 2009). The packaging must be done in the appropriate way because it can affect the stability of products in a truck during transportation. Good packaging protects the products from damage (McGregor, 1987). The use of wooden crates crush tomatoes and lead to post-harvest losses. The movement of tomatoes must be done with proper packaging in order to minimize their

deterioration and bruising during transportation (McGregor, 1987). Post-harvest losses are very high in less industrialised countries due to lack of good technologies, and lower in developed countries where the time between harvesting and consumption of the produce is shorter and transportation of produce needs to be done over shorter distances to the market (Mujib ur Rehman et al., 2007). The high moisture content of vegetables especially tomatoes makes their handling, transport, storage and marketing a big problem especially in the tropics (Babalola et al., 2010). The nutritional value, taste, flavour and quality of these fresh produce like tomato is affected by postharvest handling and storage condition (Sablani et al., 2006; Shankara et al., 2005). In Ghana the loss of tomatoes is between the range of 30% and 70% (Ellis et al., 1998). Osei et al. (2010) reported that the postharvest loss for tomatoes is 19%. In the year 2003, Ghana exported 4,368 metric tons of tomatoes, accumulating a foreign exchange of \$427,000 to the country; however, this earning dwindled to \$56,000 in 2004 as a result of post-harvest losses. To reduce post-harvest losses, farmers traders and consumers need to be trained about the new methods of preservation, packaging and appropriate storage needed to increase the shelf-life of produce especially tomato which is perishable. Roads also need to be improved in order to minimize losses during transportation.

2.6 Preservation methods

Preservation is a technique that is used to increase the shelf-life of produce by getting their maximum benefits. Each step of handling, processing, storage, and distribution affects the characteristics of food, which may be desirable or undesirable (Rahman, 2007). In Ghana the traditional food preservation methods are drying, curing, smoking, salting and fermenting. The new methods of preservation include canning, pasteurization, freezing, addition of chemicals such as edible coatings, baking and irradiation (Desrosier and Singh, 2011; Tucker, 2008). Preservation of tomato is a way of increasing income and ensuring availability of tomatoes all

year round and providing variation in diet (Rahman, 1999). The most common methods of preservation of tomatoes in Ghana are refrigeration, freezing, storage at ambient and drying mainly in the Upper East Region of Ghana (Adimabuno, 2010). The local variety of tomatoes produced in Ghana is not good for processing because it has high moisture content, low total soluble solid whereas the improved one for processing must have everything in high quantity (Robinson et al., 2010). The shelf-life of tomatoes can be increased longer depending on the processing technique, packaging material and storage conditions (Shankara et al., 2005). Consequently, there is a need to develop suitable technology for processing and preservation of tomato by reducing losses and generate additional revenue for the country (Ghavidel and Davoodi, 2010).

2.6.1 Drying

Drying is one of the oldest and important methods of food preservation (Esehaghbeygi and Basiry, 2011) from microbiological spoilage as well as pathogens (Tucker, 2008). Drying or dehydrating is a process of slowly removing moisture from a produce in order to inhibit the growth of microbes that cause spoilage and to reduce enzymatic activities (Mukhtar, 2009). This method is appropriate for tomatoes where it is used in Ghana to extend the shelf life of highly perishable produces especially vegetables after harvesting and makes them available throughout the year (Eklou et al., 2006; Habou et al., 2003). Dried tomato may be stored at room temperature in a cool, dark place (Tucker, 2008; Rahman, 2007; Holdsworth, 1971). There are different types of drying such as sun, oven and solar drying but sun drying is the most common practice (Agoreyo et al., 2011; Matazu and Haroun, 2004). Removal of water by heat in produce has been stated to affect the nutrient contents of produce, where it can increase some nutrients or decrease them (Hassan et al., 2007; Morris et al., 2004; Ladan et al., 1997). The rate of drying affects the final quality of dehydrated product (Ghavidel and Davoodi, 2010). Sun drying is defined as open air drying whereas solar drying (artificial

drying) use solar energy where more than 250, 000 000 tons of fruits and grains are dried by solar energy per annum (Rahman, 2007; Olurunda et al., 1990). Drying of vegetables is the simplest and cheapest method of preserving vegetables.

2.6.2 Edible coatings

Even drying is the traditional method of preserving vegetables in Ghana, it can be supported by the other method of extending the shelf life of tomatoes, which is the use of edible coatings. Edible coatings are thin layers of material applied to edible food products that play an important role in the preservation of foods (Falguera and others 2011). The use of edible coating is one of techniques used to conserve stored tomatoes. 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 vapour and aroma compounds, decreasing the respiration rate of the fruit, water loss, preserving texture and flavor (Olivas and Barbosa-Canovas, 2008). They protect vegetables especially tomatoes by controlling respiration rate; reducing moisture and texture loss; transporting antimicrobials, antioxidants and other preservatives; controlling microbial growth; and maintaining fruit quality for a longer period. Edible coatings have been used for extension of postharvest storage of fruits and vegetables (Allegra et al., 2016; Raffo et al., 2002; Singh et al. 2016). Edible coatings reduce fruits respiration and oxidation reaction rates. Gum-based coatings have been used widely to extend the shelf life of fruit (El-Anany et al., 2009; Maqbool et al., 2010). The edible coating is applied on the fruit surface by dipping or brushing the coating solution. An ideal edible coating can provide a partial barrier to water movement that can reduce moisture loss from the fruit surface and modify the atmosphere around the fruit by acting as a barrier to gas exchange (Jongsri, et al., 2016). An edible coating is one of the modified atmosphere methods that have shown promising results for preserving fruits quality

(Guimaraes, et al., 2018). The use of edible coatings in conjunction with low- temperature storage appears to be a promising approach to minimize many postharvest problems and preserve the freshness of tomatoes (Gonzalez-Aguilar, et al., 2010a). Materials for making coatings can be one type or a mixture of different types. One of coating materials is cassava starch which is used in less amount with low price than other starches. Cassava represents an important starch source and the cassava starch is cheap and safe (Chiumarelli et al., 2010; Garcia et al., 2010). Cassava starch edible coating is tasteless, odourless, colourless, non-toxic, biodegradable and safe, and shows low permeability to oxygen (Pareta and Edirisinghe, 2006). The use of citric acid can avoid enzymatic browning of plant tissue, thereby reducing the product appearance loss, without changing its minimally processed condition (Andrés, Giannuzzi, and Zaritzky, 2002; Brennan, Le Port, and GormLey, 2000; Moda, et al., 2005).

According to Gonzalez-Aguilar and others (2008), the incorporation of antioxidants into edible coatings can delay the negative effects of minimal processing of fruit, increasing product shelf life. Application of ascorbic acid (1%) and citric acid (0.5%) solution in fresh-cut pineapple was effective to control browning (Antoniolli, 2004).

Some edible coatings used in past studies are cassava starch and citric acid. According to Ariela, et al. (2016), 3% concentration of cassava starch was used alone and in combination of propolis on bioactive compounds in strawberries stored at 4°C for 16 days where 3% CS + 66% ethanolic propolis extract promoted higher vitamin C content than other treatments.

According to Lorena et al. (2009) three different concentrations of cassava starch (1%, 2%, and 3%) and two concentrations of potassium sorbate (0.05% and 0.10%) were used in the coatings of strawberries where it was observed for 2% and 3% starch concentration represented a possibility to extend the shelf life of fruits.

To increase product shelf-life of strawberry, cassava starch–based edible coatings (3%), added or not with potassium sorbate (0.05%), were applied on minimally processed strawberries stored up to 15 days at 5°C where cassava starch edible coatings resulted in delaying weight and firmness loss of strawberries during storage and good sensorial acceptance up to 12 days of storage. According to Julia, et al. (2020), the use of edible chitosan and citric acid (CHI–CA) coating is a promising strategy for improving the postharvest quality of fresh-cut guava fruit where the fresh-cut guava coated with CHI–CA maintained quality parameters during storage and preserved their sensorial characteristics. Therefore, the use of CHI–CA as a coating is a promising strategy for improving postharvest quality of fresh-cut fruits and preserved their sensorial characteristics.

Coating material	Composition	Fruit/vegetable	Effect of coating	References
Prolong	Mixture of sucrose fatty acid esters, sodium CMC, and mono and diglycerides	Mango	Retard ripening, reduce weight loss, and chlorophyll loss	Motlagh and Quantick, 1998
		Pear	Retention of firmness, green skin color, and titratable acidity	Farber et al., 2003
Tal Prolong	Mixture of sucrose fatty acid esters, sodium CMC, and mono and diglycerides	Mango	Delayed ripening with extended shelf life	Nisperos-Carriedo et al., 1992
Chitosan	Chitosan and Tween 80	Strawberry, cucumber, and bell pepper	Antimicrobial coatings	El-Ghaouth et al., 1991a, 1991b
		Apple, pear, plum, and peach	Act as gas barrier	Elson and Hayes, 1985; Davies et al., 1989
		Litchi	Reduced weight loss and browning, improve storability	Zhang and Quantick, 1997
		Carrot	Reduced decay and improve appearance	Cheah et al., 1997; Li and Birth, 1998
		Tomato	Reduced respiration rate, ethylene production, and increase titratable acidity	El-Ghaouth et al., 1992
		Pear	Reduced ethylene production and delay ripening as indicated by high content of titratable acidity	Li and Yu, 2000
Zein	Corn zein protein	Tomato	Delayed color change, loss of firmness and weight, and extend shelf life	Park et al., 1994
Nutri-save	N,O carboxyl methyl chitosan	Apple, pear, pomegranate	Increased shelf life	Lau and Meheriuk, 1994; Kittur et al., 2001; Srinivasa et al., 2002; Farber et al., 2003
Brilloshine	Sucrose esters and wax (shine)	Apple, avocado, melons, and citrus	Protected, increased shine and extended shelf life	Baldwin, 1994
Nu-coatFlo, Ban-seel	Sucrose esters of fatty acids and sodium salt of CMC	Apple, banana, cucumber, guava, melon, pear, and plum	Protected, increased shine and extended shelf life	Baldwin, 1994
Citrashine	Sucrose ester and wax	Mandarins	Increased shine and extend shelf life	Ahmad and Khan, 1987

Casein	Calcium caseinate	Bell pepper	Effective gas barrier to internal O ₂ and CO ₂ , inhibited color change and reduced decay	Lerdthanangkul and Krochta, 1996
	Sodium caseinate and stearic acid		Reduced moisture loss	Krochta et al., 1993
Cellulose	MC and glycerol	Carrot	Extended storage life, resulting more carotene than control	Li and Barth, 1998

2.6.3 Packaging materials

Good packaging preserve food through the prevention of product spoilage and wastage, and by protecting products until they have performed their function (Coles et al., 2003). The primary roles of packaging are to provide product containment, preservation by maintaining quality, presentation and convenience, protection and to provide information to the user. Materials that can be used as packaging include paper and board, glass, metal and plastics. The benefits of packaging may include the prevention of product damage and food spoilage, thereby saving vital nutrients, reduces or eliminates the risk of tampering and adulteration and presents food in a hygienic and often aesthetically attractive way (Manalili et al., 2011). Fresh produce quality generally decreases after harvest. Due to the increased consumption of tomatoes, there is an increased demand of different methods to improve the quality of fresh produce. Several methods including temperature control, use of efficient packaging materials, edible coatings and the use of fruits with initial good quality contribute to the reduction of postharvest losses of fruits and vegetables. Packaging can markedly extend the storage life of many fresh fruits and vegetables through the inhibition of physiological deterioration and reducing weight loss (Shetty et al., 1989 and Risse et al., 1985). Packaging and temperature are very important in terms of tomato colour and firmness as major factors in the consumer preference of tomatoes. Extending the shelf life of tomatoes is very important for domestic and export marketing. Extension of the shelf life can be achieved by the use of packaging materials like polyethylene films in storage of tomatoes. Ripening and shelf life of tomato fruits can be delayed by an

enclosure of tomato fruits in polyethylene or other forms of plastic packaging materials (Srinivasa et al., 2006).

2.7 Nutritional value

There is a wide variety of nutrients from tomatoes which provide many benefits to the body. Tomato constitutes an essential part of people's diet when consumed. It is rich in vitamins, minerals, sugars, essential amino acids, iron, dietary fibres and phosphorus (Ayandiji et al., 2011). Tomato is a source of many nutrients, where it is rich in minerals, sugars, vitamins, iron, dietary fibers and phosphorous (Ayandiji et al., 2011). Tomato is an important cash and industrial crop in many parts of the world (Ayandiji et al., 2011) not only because of its economic importance but also its nutritional value to human diet and subsequent importance in human health (Willcox et al., 2003).

2.8 Quality indices of tomato (physical chemical properties)

Depending on their temperature and harvest maturity, tomato quality can change after harvesting. Postharvest losses in tomatoes can be either quantitative or qualitative. There are different postharvest factors that can affect qualities and shelf life of stored tomatoes. It is good to take care to them, in order to conserve the optimum quality needed. The factor that affect the chemical properties of tomato include variety, environmental conditions such as temperature, light, infection, mineral nourishment and air composition and cultural norms (ripening period at harvest and irrigation scheme) (Raiola et al., 2014).

Some of the major physicochemical properties of tomatoes include fruit weight, PH, Total soluble solid, and lycopene content (Srivalli et al., 2016). Quality of most fruits and vegetables

is affected by water loss during storage, which depends on the temperature and relative humidity conditions (Perez et al., 2003).

2.8.1 The weight of tomato

The weight is the quality that everyone (farmer, Seller and Consumer) consider when they are selling or buying tomatoes, and this differ according to the varieties. The variation of tomato weight depends on different varieties (Srivalli et al, 2016). The weight loss in wrapped tomato showed a decreased in weight loss and fruits were more firm than non-wrapped tomatoes (Shetty et al., 1989; Risseet al., 1985). The weight loss of fruits and vegetables 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 weight loss due to loss of water. 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 Potential of hydrogen (pH)

The acidity of fresh tomatoes is ranging between 4.3 - 4.9% according to the centre for food safety and Applied Nutrition at the U.S. Food and Drug Administration (2007). The pH of matured tomato fruits can exceed 4.6 (Tigist et al., 2012). The pH and TA are used to indicate the development of microorganisms in tomatoes which are responsible to deterioration and decay of tomatoes. The pH increases as the TA decrease due to changes to the loss of citric acid in tomatoes (Anthon et al., 2011; Das et al., 2013).

The term pH is used to express the concentration of free H_3O^+ in a sample and results from Dissociation of the acids present. A lower pH value indicates acidity and a higher pH value indicates base. 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. A pH < 4.5 is required for processed tomato because microbial growth is inhibited. The pH of the fruit increases throughout development (Padmini, 2006). The pH of tomato increases as the storage time increase (Tigist et al., 2013).

2.8.3. Titratable acidity (TA)

Titrateable acidity (TA) is the measure of the total acid content in a food or beverage. The pH and TA are used to indicate the development of microorganisms in tomatoes which are responsible to deterioration and decay of tomatoes. The pH increases as the TA decrease due to changes to the loss of citric acid in tomatoes (Anthon et al., 2011; Das et al., 2013). Acidity in fruits is an important factor in determining maturity. According to Hu et al., (2011), wax treatment reduced titrateable 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 wax coating on longan fruit decreased their titrateable acidity during storage. Over the years it has been shown that titrateable acidity and pH contribute to the acid taste.

2.8.4 Total Soluble Solid (TSS)

The Total Soluble Solid (TSS) is the sugar content (Brix) available in tomato. Where brix is a measure of total soluble solids in a product. The high increase of TSS is due to high moisture loss. The TSS of studied tomato cultivars is ranging between 6.53° Brix to 6.93° Brix (Srivalli et al., 2016). The TSS increases when tomatoes are mature and ripen (Tigist, et al., 2013). 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). The TSS is ranging from 4.47 to 6.57° Brix (Teka, 2013). Where 6.57 is for ripen tomatoes and 4.47 for mature green tomato fruit. The total soluble solid of tomatoes increases at different temperatures and packaging materials (Park et al., 2004; Jeong et al., 2005; Nei et al., 2005). The total soluble

solids of tomatoes increased at different stages, temperatures and packaging materials (Shehla and Masud, 2007; Abdullah et al., 2004). The soluble solids content 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. Soluble solids content varies between cultivars and between stages of ripeness (Hibler and Hardy, 1994). 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 synthases which is activated by the ripening process itself, by ethylene, and by cool storage (Mitchell et al., 1991). 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 Lycopene

Lycopene is a natural antioxidant in tomato responsible to the protection against epithelial cancers (Brandt et al., 2006). It is the pigment which is predominantly responsible for the red colour of ripe tomato fruits (Shi and Maguer, 2000). It works as a micronutrient and other health benefits (Viuda-Martos, 2013). The antioxidant helps to prevent prolonged diseases connected to oxidative trauma, like cancer and coronary artery disease. Lycopene has also been shown to be the most potent antioxidant produced by the carotenoid's pathway (Cox, 2001). Lycopene is depending on some environmental factor like temperature where the temperature around 30⁰c cause the loss of lycopene in tomatoes. The lycopene content of tomatoes samples ranged from 1.21 to 6.43 mg/100 g for fresh tomato (Hamulka and Wawrzyniak, 2004). It is also ranging between 6.88- 7.83 mg/100g for different varieties (Mohammed et al. (2017) the same with Mohammed and Malami (2013) where lycopene is ranging between 3.79- 17.53 mg/100g). The storage conditions may reduce the lycopene content, degrade it completely, thus rendering the food undesirable to the consumer (Xianquan et al., 2005). Sesso et al., (2003) also found that lycopene might help reduce risk of heart disease. Some researchers found that

women who ate at least seven servings a week of tomato-based products had a 30% reduced risk of cardiovascular diseases. 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). Lycopene is also the key colouring agent for the red colour of tomatoes (Lavelli and Scarafoni, 2011; D'Sousa et al., 2008). At higher temperatures the lycopene content decreased more, and losses of 17.1% were observed at 130°C (Miki and Akatsu, 1970).

2.8.6. Fruit firmness

Firmness determines whether or not fruit can be transported to distant markets without deterioration. Tomato fruit becomes very soft during ripening (Hanson, 2001). The firmness is one of quality indices related to fruit development, maturity, ripening and storage potential. (Dobrzanski and Rybezyski, 1998) firmness is the principal characteristic 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, shrivelling or decay (Sargent and Moretti, 2002). Bosland (1993) stated that, firmness can be affected by ripening process, post-harvest handling and also the temperature). Lownds et al. (1993) indicated that the fruit firmness was increased as the weight loss increase during prolonged storage of pepper and other vegetables.

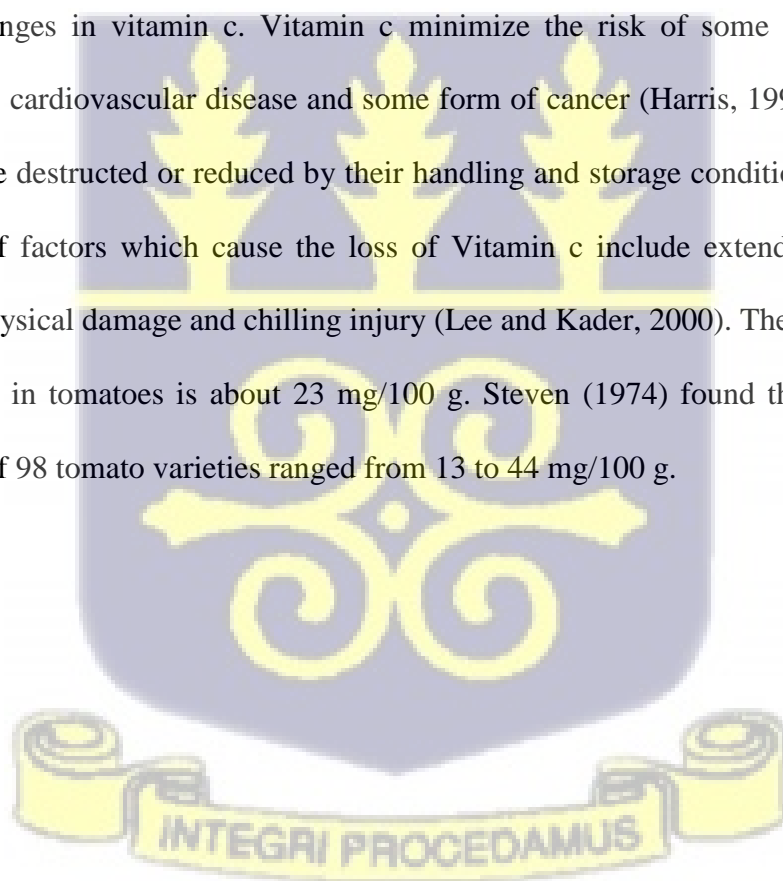
2.8.7 Shelf life

Shelf life is defined as the period in which a product should maintain a predetermined level of quality under specified storage condition. 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 mineral oil wax could be good 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 was very effective in improving the overall quality and extending the shelf life of sweet orange fruits at room temperature. Nurul (2012) 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. The rapid quality loss at relatively short period of 4-7 days is the main reason to reduce post-harvest losses of fruits and improve the quality and acceptability in the consumer market (Thompson et al., 1998). Sugri et al. (2010), also noted that shea butter as a food-grade wax on plantain

2.8.8 Vitamin c (Vit.c)

Tomato is a very important source of vitamin c. Post-harvest handling and storage conditions may cause changes in vitamin c. Vitamin c minimize the risk of some diseases such as arteriosclerosis, cardiovascular disease and some form of cancer (Harris, 1996). Vitamin c of tomatoes can be destructed or reduced by their handling and storage conditions (Arias, et al., 2000). Some of factors which cause the loss of Vitamin c include extended storage, high temperature, physical damage and chilling injury (Lee and Kader, 2000). The average vitamin c concentration in tomatoes is about 23 mg/100 g. Steven (1974) found that the vitamin c concentration of 98 tomato varieties ranged from 13 to 44 mg/100 g.



CHAPTER THREE: MATERIALS AND METHODS

The methodology aimed at determining the effect of cassava starch, citric acid and their combinations as edible coatings. Polyethylene and plastic bags as packaging materials on quality of two varieties of tomatoes. The 1st experiment studied the effect of coatings on the quality of tomatoes. Tomato samples which showed desired quality in the 1st experiment were taken in the 2nd experiment to check the quality of two varieties of tomatoes (pectomech and wosowoso) when coated and covered in polyethylene and plastic bags. Tomato samples in the two experiments were kept at room and refrigeration temperatures.

3.1 Collection of samples

The samples that were used in the study were two varieties of tomatoes, Pectomech (P) and Wosowoso (W). They were purchased according to uniform size and colour from Madina market, Accra, Ghana. They were packed into polyethylene bags and brought to the Post-harvest laboratory of Crop Science department, University of Ghana, Legon, Ghana for further treatments. The coating materials used, were cassava starch, citric acid and their combination (cassava starch and citric acid). The non-coated tomatoes were used as a control. The following concentrations were used: 1, 2 and 3% for cassava starch, 0.5 and 1% for citric acid and finally 1:0.5, 1:1, 2:0.5, 2:1, 3:0.5 and 3:1 ratio for cassava starch: citric acid. The two packaging materials used were polyethylene bags and plastic baskets. The coated and non-coated tomatoes were stored at 4°C in the refrigerator and at 28°C at room temperature. Tomatoes, cassava starch, polyethylene bags and plastic baskets were purchased from Madina market, Accra, Ghana.

3.2. Preparation of samples and coating materials

3.2.1. Tomatoes

All purchased tomatoes were sorted to remove tomatoes showing softness, physical damages, sunburn, decay, cracks, non-red colour. The stems were detached from the tomatoes. Wanted tomatoes were manually washed 3 times in tap water to remove dust, mud, dry leaves, stems, applied chemicals (ex.:pesticides) and other external non chemical contaminants. Washed tomatoes were stored at 4°C in the refrigerator until further treatments. The solid and liquid wastes were disposed in appropriated bins provided in the laboratory.

3.2.2. Coating materials

The coating materials used in the study were cassava starch and citric acid.

Cassava starch was purchased from Madina market, Accra, Ghana, and citric acid was provided in the Post-harvest laboratory of Crop Science Department, University of Ghana, Legon.

3.2.2.1 Cassava starch

The concentrations of cassava starch used for the experiment were 1, 2 and 3%. The preparation of the concentrated cassava starch was performed according to Wheatley and Zakhia (2003). Cassava starch slurry at 1% was prepared by mixing 10g of cassava starch with 990 mL of distilled water. This was then heated on an electric stove (capacity: 12 inch, ID22270119188, India) up to a temperature of 80 °C until it gelatinized (C.C. Wheatley and N. Zakhia 2003). The slurry was then allowed to cool to 40oC before it was applied on the tomatoes. The same procedure was used to prepare the different concentrations (2% and 3%) by using 20 g and 30 g cassava starch in 980 and 970 mL of distilled water respectively.

3.2.2.2 Citric acid

Citric acid concentrations used were as follows: 0.5 and 1%. The 0.5% of citric acid solution was prepared by mixing 5g of citric acid with 995ml of distilled water, and 1% by mixing 10g of citric acid with 990ml of distilled water.

3.2.2.3 Cassava starch and citric acid combination

The concentration for the combination of citric acid (CA) and cassava starch (CS) were 1:0.5, 1:1, 2:0.5, 2:1, 3:0.5 and 3:1 ratio. The 1:0.5 ratio was prepared by mixing 10g of cassava starch with 5g of citric acid to obtain their mixture of 15g. This mixture of CS and CA was mixed with 985ml of distilled water. This was heated on an electric stove up to a temperature of 80°C until it gelatinized. The slurry was also allowed to cool to 40°C before it was applied to the tomatoes. The same procedure again was used to prepare the remaining concentrations (1:1, 2:0.5, 2:1, 3:0.5, and 3:1) by using 20 g, 25g, 30g, 35g, and 40g of mixture in 980, 975, 970, 965 and 960 mL of distilled water respectively.

3.3. Coating of tomatoes

Tomatoes were coated with prepared solutions of cassava starch and citric acid (See table 3.1) by using the method of Menezes and Athmaselvi (2016). Tomatoes were dipped for 2 min and allowed to dry in open air. The 1st category of dry tomatoes was not packed and the 2nd category was packed in polyethylene bags and plastic baskets. Both categories were kept at 4°C in refrigeration and at 28°C in open air.

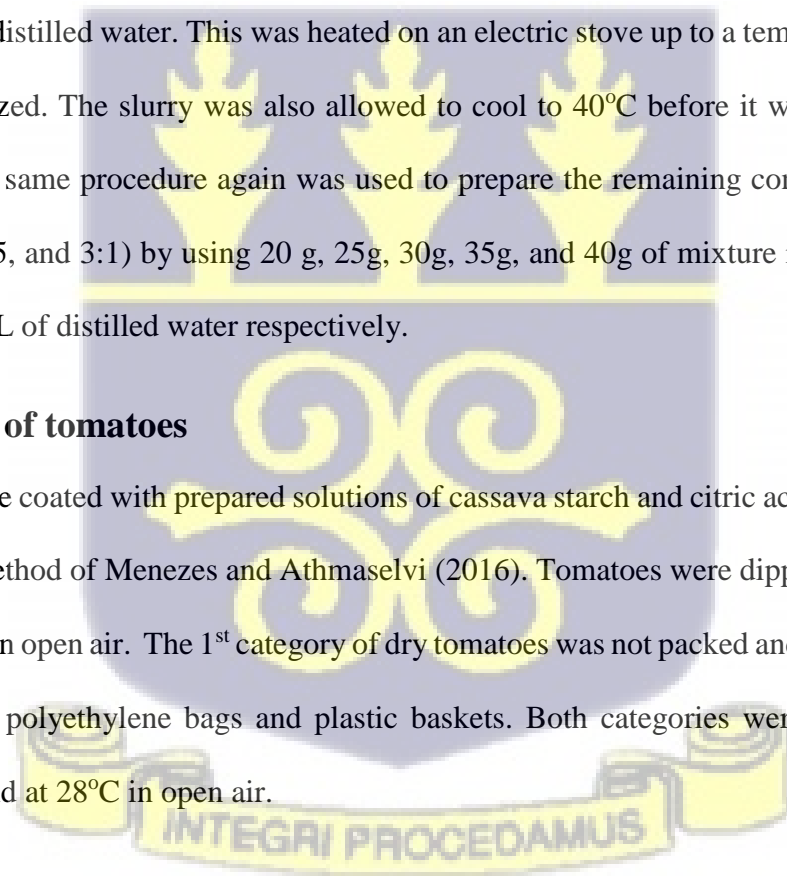


Table 3.1 DESCRIPTION OF MATERIALS AND TREATMENTS RATIOS

Coating material	Percentage and ratio	Method of Application
Cassava starch (CS)	1%	Dipping
Cassava starch	1%	Brushing
Cassava starch	2%	Dipping
Cassava starch	2%	Brushing
Cassava starch	3%	Dipping
Cassava starch	3%	Brushing
Citric acid (CA)	0.5%	Dipping
Citric acid	0.5%	Brushing
Citric acid	1%	Dipping
Citric acid	1%	Brushing
Cassava starch + Citric acid	1:0.5	Dipping
Cassava starch + Citric acid	1:0.5	Brushing
Cassava starch + Citric acid	1:1	Dipping
Cassava starch + Citric acid	1:1	Brushing
Cassava starch + Citric acid	2:0.5	Dipping
Cassava starch + Citric acid	2:0.5	Brushing
Cassava starch + Citric acid	2:1	Dipping
Cassava starch + Citric acid	2:1	Brushing
Cassava starch + Citric acid	3:0.5	Dipping
Cassava starch + Citric acid	3:0.5	Brushing
Cassava starch + Citric acid	3:1	Dipping
Cassava starch + Citric acid	3:1	Brushing
Control	-	Dipping
Control	-	Brushing

3.4. Determination of physicochemical properties of coated tomatoes

The quality indices that were measured were shelf-life, weight loss, firmness, total soluble solids, pH, titratable acidity, vitamin C and lycopene.

3.4.1. Shelf- life

The shelf life of four tomatoes from each sample was determined by counting their life number of days before deterioration during their storage time.

3.4.2. Weight loss

According to the weight loss, four tomatoes from each treatment were weighed at the start of the experiment as initial weight (W_i) and every two days fruits were reweighed for final weight (W_f). To determine the weight loss in the fruits during 37 days of storage time, the weight was measured using the weighing laboratory scale (ID: 2945712791, India MART).



Figure 3.1. Laboratory scale used by measuring the weights of tomatoes every two days.

The weight loss was expressed as percentage using the following equation:

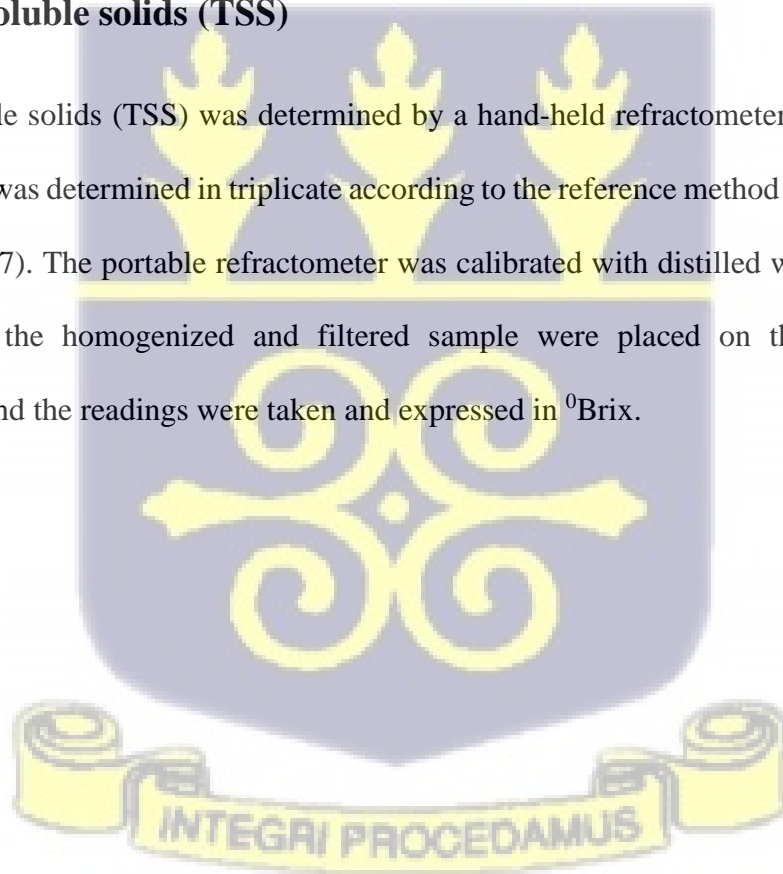
$$\% \text{ weight loss} = \{(W_i - W_f)/W_i\} \times 100. \text{ (Hosseini et al., 2019).}$$

3.4.3 Firmness

Firmness was determined by using an FT 011, 0–11 lb, penetrometer (Facchini, Alfonsine, Italy). The replicates were three tomatoes sampled randomly from each treatment and their firmness was determined according to the manufacturer's instructions. To determine the resistance of the fruit to penetration with a rod of 8.0 mm diameter for soft fruits. The rod was placed perpendicularly on the tomato and the fruit was pressed to cause a gradual visible cut, at which point the measurement was recorded (OECD 2009).

3.4.4 Total soluble solids (TSS)

The total soluble solids (TSS) was determined by a hand-held refractometer (JENA 178512) where the TSS was determined in triplicate according to the reference method 920.151 reported by AOAC (1997). The portable refractometer was calibrated with distilled water and 3 drops of juice from the homogenized and filtered sample were placed on the prism of the refractometer and the readings were taken and expressed in °Brix.



3.4.5 Potential of hydrogen (pH)

The pH was determined by using a pH meter (Mettler Tolleo EL20-Kit Benchtop Education pH Meter). The pH values were measured from juice of three different tomatoes taken randomly in each sample and pH values of their juice were measured according to Association of Official Analytic Chemist (AOAC) method (1990). The Buffers 4,7,10 were used to calibrate pH meter where the sensor electrodes were rinsed with distilled water and soaked in a glass that contained a solution of water and buffer until the pH level stabilized and the pH meter correctly matched the pH value of the calibration solution.



Figure 3.2: The pH meter used for measuring the pH of tomatoes

3.4.6 Titratable acidity (TA)

The titratable acidity was determined by titration with bromthymol blue indicator following this way: 20.00 cm³ of sample was pipetted for the analysis, 2.00 cm³ of working solution of indicator was added and titrated by the solution of potassium hydroxide till changing the indicator colour. Three titrations were done and average consumption of the base solution was

calculated (Daničić, 1984). Titration with indicator phenolphthalein was also done in the same way, till the colour changing to pink (Rajković and Novaković, 2005).

3.4.7 Lycopene

The lycopene was determined using the Spectrophotometric method. A mixture of hexane: ethanol: acetone at 2:1:1 (v/v) was used for lycopene extraction (Sadler et al. 1990). In this procedure, 1 gram of tomato juice and 100 ml of the mixed solvents were used. An aliquot of tomato homogenate was weighed into a flask, the solvent was added and the lycopene was allowed to extract over the next 15 to 30 min. Water was added (15ml per 100ml of solvent) to cause a phase separation. The upper hexane phase contained all the lycopene was quantified spectrophotometrically as it has been used by other investigators (Sharma and Le Maguer, 1996; Arias et al., 2000; Gordon and Diane, 2007; Godwin, et al., 2015).

3.4.8 Vitamin C

Vitamin c was determined by using Indophenol Method (Zvaigzne G., Karklina.D, Seglina D. and Krasnova I, 2009) 10 g of each of the tomato samples was accurately weighed and ground using mortar and pestle with an additional of 20 ml of metaphosphoric acid acetic acid. The mixture was further ground and strained through muslin and the extract was made up to 100 ml with the metaphosphoric-acetic acid mixture. 5 ml of the metaphosphoric acid-acetic acid solution was pipetted into three of the 50 ml Erlenmeyer flask followed by 2 ml of the samples extract. The samples were titrated separately with the indophenol dye solution until a light rose pink persisted for 5 s. The amount of dye used in the titration were determined and used in the calculation of vitamin C content.

3.5. Sensory evaluation

The visual quality of stored coated and packed tomatoes was assessed by 10 trained panellists from Family and Consumer Sciences department, School of Agriculture, College of Basic and Applied Sciences, University of Ghana, Legon. A five – point hedonic scale was used to score samples for appearance, texture, colour and overall acceptability.

3.6. Statistical data analysis

In the 1st experiment, the Pectomech tomatoes were stored at room and refrigeration temperatures after coating them with cassava starch, citric acid and their combinations in different concentrations by brushing and dipping. The coated tomato samples which showed desired quality in the 1st experiment were taken in the 2nd experiment as two varieties (pectomech and wosowoso) to be packed in polyethylene and plastic bags during storage at room and refrigeration temperatures.

A 12x2x2 factorial experiment layout in a completely randomized design with 48 samples was used in experiment 1 (coating of tomatoes) and a 2x2x2x2 factorial experiment layout was used for experiment 2 (packaging of tomatoes) with 16 Samples. All treatments were replicated 3 times. All data obtained from the laboratory experiments and the sensory evaluation were analysed using analysis of variance (ANOVA) with computer GenStat program and the means were separated using Duncan multiple range test at a level of significance of $P < 5\%$.



CHAPTER FOUR

4.0. RESULTS

4.1. Experiment One

The present results are for the 1st experiment in which different coatings and coating techniques were used to preserve uncovered tomato varieties during storage at room and refrigeration temperatures. The Pectomech tomato were coated with cassava starch and citric acid and their combinations in different concentrations by brushing and dipping.

4.1.1 Effect of edible coatings on shelf-life of pectomech tomatoes stored at room temperature and at refrigeration

Figure 4.1 and 4.2 show the shelf-life of pectomech tomatoes coated with different edible coatings and stored at room temperature (28°C) and refrigeration temperature (4°C) for up to 35 days.

From the results, it was observed that the control samples had shorter shelf life than other tomato samples.

For dipping method (figure 4.1), tomatoes which showed the longest shelf life (35 days) at refrigeration storage were coated with 2% CS; 1:0.5 CS:CA; 2:0.5CS:CA; 3: 0.5 CS:CA and 3:1 CS:CA while at room storage, tomatoes with the longest shelf life (21 days) were coated with 0.5% CA; 1% CA; and 3:1% CS: CA.

For brushing method (figure 4.2), tomatoes which showed longest shelf life (35 days) at refrigeration temperature were coated with 1%Cs; 0.5% CS; 1% CA; 1:1 CS:CA and 2:1 CS:CA while at ambient temperature, tomatoes which showed the longest shelf life (28 days) were coated with 1% CS; and 1:1 CS:CA.

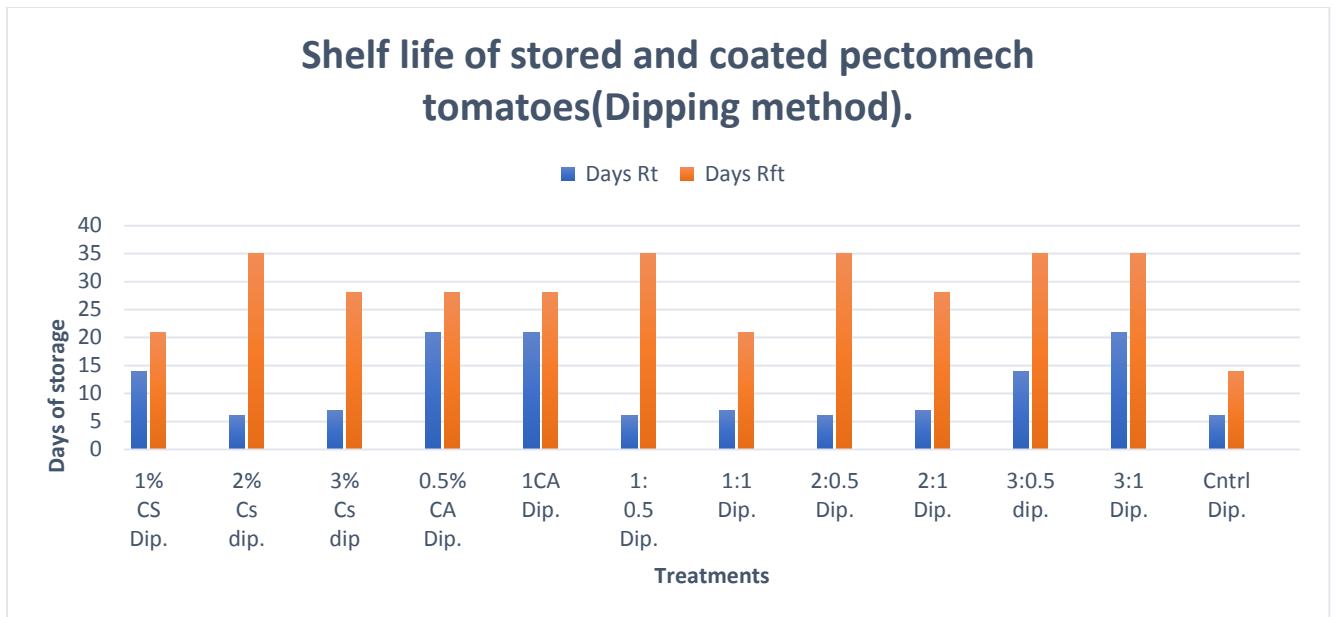


Figure 4.1: Effect of edible coatings on shelf life of tomatoes stored at room temperature (28° C) and in refrigeration (4°C) with dipping method

Note: CS: Cassava starch coating, CA: citric acid coating, Brush: brushing method, Cntrl: control; Days Rt: days of storage in room temperature (28°C), Days Rft: Days of storage in refrigeration temperature (4°C)

1CS Dipp: 1% concentration of cassava starch coating with dipping method. The same with the others respectively.

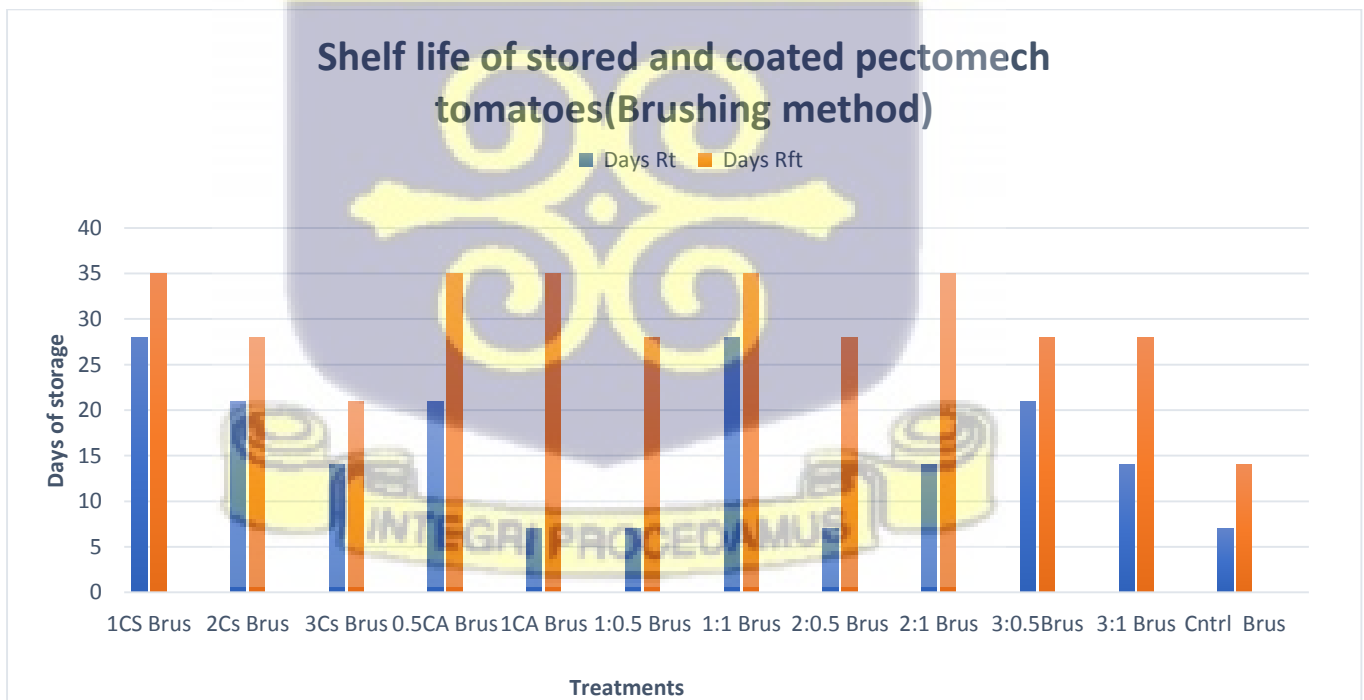


Figure 4.2 Effect of edible coatings on shelf-life of tomatoes stored at room temperature and in refrigeration with brushing method.

Note: 1CS Brus: 1% concentration of Cassava starch coating with brushing method

0.5 CA Brus: 2% concentration of Citric acid coating with brushing method

1:0.5 Brus: 1% Cassava starch mixed with 0.5 Citric acid coating with brushing method...

4.1.2 Effect of edible coatings on weight loss of pectomech tomatoes stored at room temperature and at refrigeration

Figure 4.3 and 4.4 show the weight loss of pectomech tomatoes coated with different edible coatings by dipping and brushing methods, and stored at room temperature (28°C) and refrigeration temperature (4°C) for up to 35 days. The results, indicated that, there was a significant increase ($P < 0.05$) in weight loss value of stored tomatoes.

From the results, it was observed that for control samples which were dipped in distilled water had a low weight loss compared to samples brushed in distilled water. For both method of applications, the weight loss at refrigeration temperature was lower than that at room storage.

For samples which were stored at room temperature (28°C) and refrigeration temperature (4°C) and dipped in cassava starch (2% CS), showed the lower weight loss than samples dipped in 1 or 3% CS treatments. The samples which were stored at room temperature (28°C) and refrigeration temperature (4°C) and brushed in cassava starch (1% CS), showed the low weight loss than samples brushed in 2 or 3% CS treatments.

Comparing both method of applications, in dipping method (2% CS) showed lower weight loss than brushing method (1% CS).

For citric acid coating, the samples which were stored at room temperature and refrigeration temperature, and dipped in 0.5% CA treatment, had low weight loss than samples dipped in 1% CA, while the samples which were stored at room temperature and refrigeration temperature, and brushed in 1% CA treatment showed low weight loss than 0.5% CA

treatment. Comparing both method of applications, brushed samples in 1% CA showed the low weight loss than samples dipped in 0.5% CA.

For cassava starch mixed with citric acid, the samples which were stored at room temperature and dipped in 1:1 CS+CA treatment showed low weight loss than other treatments, while in refrigeration 3:1 CS+CA was the one which showed the low weight loss than other combinations.

The samples which were stored at room temperature and refrigeration temperature and brushed in 3:1 CS+CA treatment showed the low weight loss than other combinations.

Comparing both method of applications, The samples which were stored in room and brushed in 3:1% CS+CA showed the low weight loss than samples dipped in 1:1CS+CA, while the samples which were stored in refrigeration, and dipped in 3:1 CS+CA showed the low weight loss than samples brushed in 3:1 CS+CA.

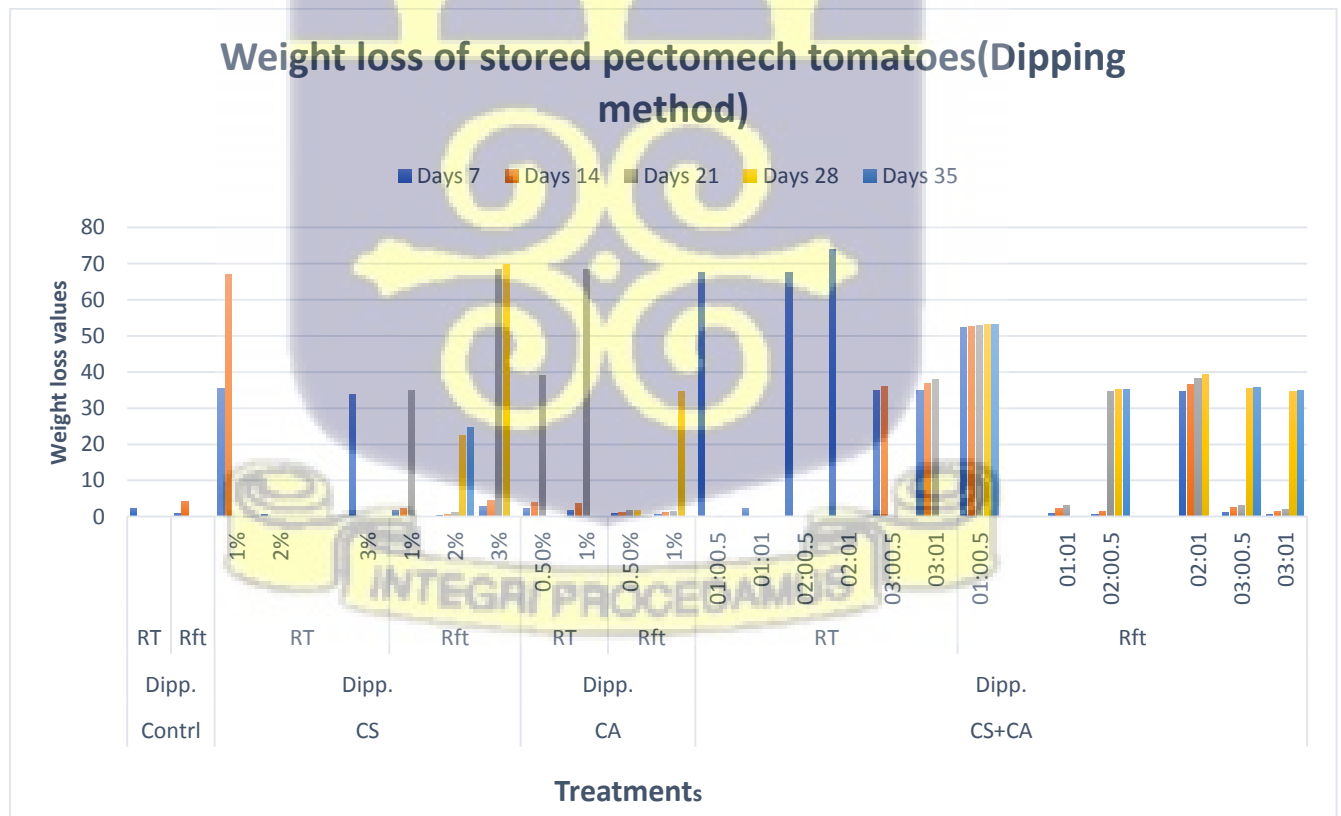


Figure 4.3: Effect of edible coatings on weight loss of tomatoes stored at room temperature and in refrigeration with dipping method.

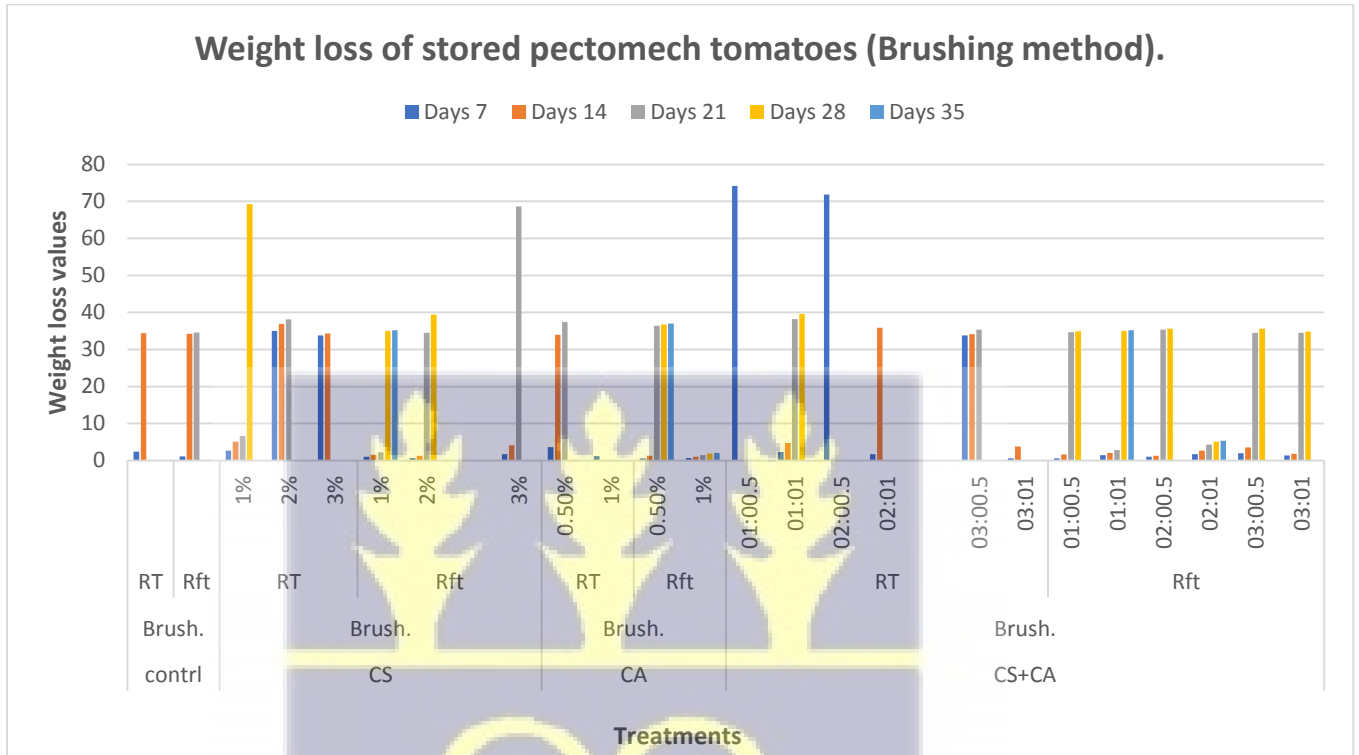


Figure 4.4: Effect of edible coatings on weight loss of tomatoes stored at room temperature and at refrigeration with brushing method.

4.1.3: Effect of edible coatings on the total soluble solid (TSS) of pectomech tomatoes stored at room temperature and at refrigeration.

Table 4.1 (a,b) shows the changes in total soluble solid of pectomech tomatoes coated with different edible coatings and stored at room temperature (28°C) and refrigeration temperature (4°C) for up to 21 days. The results, indicated that, there was a significant increase ($P < 0.05$) in total soluble solid (TSS) value of stored tomatoes.

From the results it was observed that the control samples which were dipped in distilled water and stored at room temperature (28°C) or at refrigeration temperature (4°C) had a TSS value of 7.25 and 6.31 on day 7 respectively whereas the control samples which were brushed in distilled water and stored at room temperature (28°C) or at refrigeration temperature (4°C) had a TSS value of 5.13 and 3.18 on day 14 respectively.

The coated samples which were dipped in 1% CS and stored at room temperature (28°C) or at refrigeration temperature (4°C) had a TSS value of 4.15 and 2.59 on day 14 respectively while the samples which were brushed in 1% CS and stored at room temperature (28°C) or at refrigeration temperature (4°C) had a TSS value of 4.54 and 4.43 on day 14 respectively.

The coated samples which were dipped in 3% CS and stored at room temperature (28°C) or at refrigeration temperature (4°C) had a TSS value of 4.46 and 4.34 on day 7 respectively while the samples which were brushed in 3% CS and stored at room temperature (28°C) or at refrigeration temperature (4°C) had a TSS value of 4.40 and 3.00 on day 7 respectively.

The coated samples which were dipped in 0.5% CA and stored at room temperature (28°C) or at refrigeration temperature (4°C) had a TSS value of 5.69 and 4.91 on day 21 respectively, while the samples which were brushed in 0.5% CA and stored in refrigeration temperature (4°C) had a TSS value of 2.94 on day 21.

The coated samples which were dipped in citric acid (1% CA) and stored at room temperature (28°C) or at refrigeration temperature (4°C) had a TSS value of 6.99 and 4.64 on day 21 respectively, whereas the samples which were brushed in 1% CA and stored at refrigeration temperature (4°C) had a TSS value of 5.58 on day 21.

The coated samples which were dipped in cassava starch mixed with citric acid (3:1 CS+CA) and stored at room temperature (28°C) or at refrigeration temperature (4°C) had a TSS value

of 4.92 and 4.65 on day 21 respectively, whereas the samples which were brushed in (3:1, CS + CA) and stored at refrigeration temperature (4°C) had a TSS value of 4.59 on day 21.

Table 4.1(a). Changes in TSS according to different coating materials

Coating material	Method of application	Storage place	%	Days			
				0	7	14	21
Control	Dipping	Rt		3.77c	7.25n	N/A	N/A
		Rft		3.23a	6.31m	5.13jk	N/A
	Brushing	Rt		3.64abc	4.100cd	3.81b	4.37bc
		Rft		3.23a	3.80de	2.59ab	N/A
Cassava starch	Dipping	Rt	1	3.68bcde	4.99ij	4.15cde	N/A
			2	3.8cdef	N/A	N/A	N/A
			3	3.63abc	4.46ghij	N/A	N/A
		Rft	1	3.65 abc	4.24cde	2.59ab	N/A
			2	3.23a	3.68bc	4.10fgh	3.58ab
			3	TSS	3.93ef	4.34efgh	5.43h
	Brushing	Rt	1	3.80cdef	5.37h	4.57defg	4.41c
			2	3.63abc	4.88f	6.07i	5.51e
			3	3.53bcd	4.40efgh	N/A	N/A
		Rft	1	3.45b	4.18defg	4.43hij	3.54ab
			2	4.18cde	4.82ij	4.41hij	5.13de
			3	3.23a	3.00a	3.73abc	N/A
Citric acid	Dipping	Rt	0.5	3.76cdef	3.60bc	5.15g	5.69efj
			1	3.34abc	4.53fghi	6.96 l	6.99j
		Rft	0.5	3.81bc	3.06a	4.67efg	4.91d
			1	3.89bc	4.35def	5.18gh	4.64cd
	Brushing	Rt	0.5	3.31ab	4.92fgh	4.57fg	N/A
			1	4.79jk	N/A	N/A	N/A
		Rft	0.5	3.01a	4.29de	4.15cde	2.94a
			1	3.64abc	5.64kl	5.39hi	5.58ef

Data are presented as means±SD. Means within a column with different letters are significantly different at P≤0.05

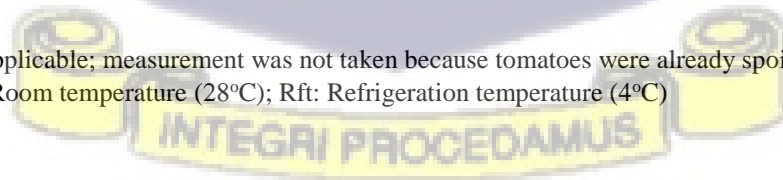
Notes: N/A: Not Applicable; measurement was not taken because tomatoes were already spoiled; TSS: total soluble solid; Rt: Room temperature (28°C); Rft: Refrigeration temperature (4°C)

Table 4.1(b). Changes in TSS according to different coating materials

Coating material	Method of application	Storage place	Ratio	Days					
				0	7	14	21		
Cassava starch +Citric acid	Dipping	Rt	1:0.5	3.70bcd	5.63kl	N/A	N/A		
			1:1	3.25a	5.18hijk	4.95fgh	N/A		
			2:0.5	4.15fgh	4.94gh	N/A	N/A		
			2:1	3.50bc	4.99gh	4.96fgh	N/A		
			3:0.5	3.82def	4.13cdef	4.96k	4.42c		
			3:1	3.24ab	5.94 l	4.88jk	4.92d		
			Rft	1:0.5	3.86bc	3.28a	3.89efg	3.94b	
			1:1	3.66def	4.99gh	4.36ghij	4.65cd		
			2:0.5	3.62abc	4.15cdefg	4.10fgh	4.40c		
			2:1	3.36ab	4.99gh	4.84hij	N/A		
			3:0.5	3.52bc	3.99bcd	4.49def	4.07abc		
			3:1	3.73bcde	4.75fg	4.31cdef	4.65cd		
			Brushing	Rt	1:0.5	3.55bcd	N/A	N/A	N/A
			1:1	3.99ef	4.61efg	5.99ijk	4.10bc		
			2:0.5	3.67def	N/A	N/A	N/A		
2:1	4.01efg	4.70ghij	N/A	N/A					
3:0.5	3.19a	5.94 l	5.77i	N/A					
3:1	3.10a	6.15lm	4.72hij	N/A					
Rft	1:0.5	3.36ab	3.95cde	3.46ab	5.46ef				
1:1	3.15a	3.59bc	2.36a	3.94b					
2:0.5	3.71a	5.17jk	3.95bcd	5.26ef					
2:1	3.20a	3.96b	4.33ghi	5.23def					
3:0.5	3.77bc	5.46l	2.43a	4.10bc					
3:1	3.74b	4.96gh	3.84cde	4.59bcd					

Data are presented as means±SD. Means within a column with different letters are significantly different at P≤0.05

Note: N/A: Not Applicable; measurement was not taken because tomatoes were already spoiled; TSS: total soluble solid; Rt: Room temperature (28°C); Rft: Refrigeration temperature (4°C)



4.1.4 Effect of edible coatings on firmness of pectomech tomatoes stored at room temperature and at refrigeration

Table 4.2 (a,b) shows the changes in firmness of pectomech tomatoes coated with different edible coatings and stored at room temperature (28°C) and refrigeration temperature (4°C) for up to 21days. The results, indicated that, there was a significant decrease ($P<0.05$) in the firmness of coated stored tomatoes.

For the control samples which were dipped in distilled water and stored at room temperature (28°C) or at refrigeration temperature (4°C) had the firmness value of 3.44 and 7.19 on day 7 respectively, while the samples which were brushed in distilled water and stored at room temperature (28°C) or at refrigeration temperature (4°C) had the firmness value of 2.28 and 2.95 on day 14 respectively.

For the samples which were dipped in Cassava starch (1%) and stored at room temperature (28°C) or at refrigeration (4°C) showed the firmness value of 2.73 and 5.80 on day14 respectively, however the samples dipped in Cassava starch (3% CS) and stored at room temperature (28°C) or at refrigeration (4°C) had the firmness value of 2.64 and 10.66 on day7 respectively.

The samples which were brushed in Cassava starch (1%) and stored at room temperature (28°C) or at refrigeration (4°C) showed the firmness value of 2.57 and 2.87 on day 21 respectively. However, the samples brushed in Cassava starch (2% CS) and stored at room temperature (28°C) or at refrigeration (4°C) showed the firmness value of 3.30 and 3.79 on day 21 respectively while the samples brushed in Cassava starch (3% CS) and stored at room temperature (28°C) or at refrigeration (4°C), showed the firmness value of 5.11 and 10.18 on day 7 respectively.

The samples which were dipped in citric acid (0.5% CA) and stored in room temperature (28°C) or at refrigeration at 4°C showed the firmness value of 2.74 and 3.54 on day 21 respectively

while the samples dipped in (1% CA) and stored at room temperature (28°C) or at refrigeration at 4°C had the firmness value of 2.49 and 2.65 on day 21 respectively.

However, the samples which were brushed in Citric acid (0.5% CA) and stored at room temperature (28°C) or at refrigeration (4°C) showed the firmness value of 3.36 and 3.99 on day14 respectively.

The samples which were dipped in Cassava starch mixed with citric acid (3:0.5%) and stored at room temperature (28°C) or at refrigeration (4°C) showed the firmness value of 4.15 and 5.18 on day 21 respectively, while the samples dipped in (3:1% CA) and stored at room temperature (28°C) or at refrigeration (4°C) had the firmness value of 7.54 and 9.49 on day 21 respectively.

The samples brushed in Cassava starch mixed with citric acid (3:0.5% CS) and stored at room temperature (28°C) or at refrigeration (4°C) had the firmness value of 3.58 and 4.06 on day 21 respectively and the samples which were brushed in Cassava starch mixed with citric acid (3:1% CS) and stored at room temperature (28°C) or at refrigeration (4°C) showed the firmness value of 2.63 and 6.79 on day 14 respectively.

Table 4.2 (a). Changes in firmness according to different coating materials

Coating material	Method of application	Storage place	%	Days			
				0	7	14	21
Control	Dipping	Rt		10.94g	3.44b	N/A	N/A
		Rft		10.88g	7.19h	3.10a	N/A
	Brushing	Rt		7.18a	2.94ab	2.28a	N/A
		Rft		7.36ab	3.52n	2.95a	2.57fg
Cassava starch	Dipping	Rt	1	8.75cd	3.13gh	2.73ab	N/A
			2	8.94d	N/A	N/A	N/A
			3	7.13a	2.64a	N/A	N/A
		Rft	1	8.78cd	7.63f	5.80g	N/A
			2	7.18a	4.85d	3.77de	3.31c
			3	7.51b	10.66ij	8.88i	3.15b
	Brushing	Rt	1	Firmness 7.63bc	3.78de	2.65ab	2.57a
			2	10.23ef	6.41e	4.48f	3.30g
			3	7.35ab	5.11d	N/A	N/A
		Rft	1				
			2				
			3				

Citric acid	Dipping	Rft	1	7.72bc	4.15a	3.13bc	2.84 a
			2	10.29nef	5.41efg	5.20c	3.79c
			3	7.36ab	10.18I	8.91i	N/A
		Rt	0.5	10.55f	8.19k	5.38f	2.74a
			1	10.37ef	4.97g	3.86b	2.49a
			Rft	0.5	10.59f	15.41 l	4.49d
	Brushing	Rt	1	8.94d	8.58g	3.96c	2.65a
			0.5	9.04d	5.15d	3.36cd	N/A
			1	8.15c	N/A	N/A	N/A
		Rft	0.5	9.41de	5.15d	3.99c	2.53a
			1	9.98e	6.49d	3.69c	2.94ab

Data are presented as means±SD. Means within a column with different letters are significantly different at $P \leq 0.05$

Note: N/A: Not Applicable; measurement was not taken because tomatoes were already spoiled; TSS: total soluble solid; Rt: Room temperature (28°C); Rft: Refrigeration temperature (4°C)

Table 4.2 (b). Changes in firmness according to different coating materials

Coating material	Method of application	Storage place	Ratio	Days				
				0	7	14	21	
Cassava starch +Citric acid	Dipping	Rt	1:0.5	9.73de	2.41a	N/A	N/A	
			1:1	9.61de	3.13b	2.97bc	N/A	
			2:0.5	9.92 e	2.81a	N/A	N/A	
			2:1	10.68fg	6.15ij	3.71d	N/A	
			3:0.5	10.61f	5.71hi	5.41d	4.15cd	
			3:1	8.15c	10.68f	11.57m	7.54f	
			Rft	1:0.5	9.73de	5.94m	2.37a	2.36a
				1:1	9.49de	13.02g	3.13a	3.09bc
				2:0.5	8.97d	4.55b	2.77ab	2.43a
				2:1	10.74m	7.65f	5.96e	N/A
	3:0.5	10.15jk		5.64m	5.47de	5.18ef		
	Brushing	Rt	3:1	8.15 c	11.52k	11.62k	9.49h	
			1:0.5	7.57b	N/A	N/A	N/A	
			1:1	7.15a	9.41l	4.82e	2.43a	
			2:0.5	8.86cd	N/A	N/A	N/A	
			2:1	10.65fg	4.65b	N/A	N/A	
			3:0.5	10.41efg	8.57hi	5.23gh	3.58cd	
			3:1	7.36ab	10.50j	2.63ab	N/A	
			Rft	1:0.5	7.58b	7.23ef	3.49cd	2.68ab
				1:1	7.15a	8.57g	4.99e	2.76a
2:0.5				8.75cd	8.97gh	5.68c	3.79d	
2:1	10.75o	12.15j		6.46e	4.15ef			
3:0.5	9.37d	8.62j		6.51d	4.06d			
3:1	7.35ab	11.42k	6.79de	4.65d				

Data are presented as means±SD. Means within a column with different letters are significantly different at $P \leq 0.05$

Notes: N/A: Not Applicable; measurement was not taken because tomatoes were already spoiled; TSS: total soluble solid; Rt: Room temperature (28°C); Rft: Refrigeration temperature (4°C)

4.1.5. Effect of edible coatings on the lycopene of pectomech tomatoes stored at room temperature and at refrigeration

Figure 4.5 and 4.6 show the changes in lycopene of pectomech tomatoes coated with different edible coatings by dipping and brushing methods and stored at room temperature (28°C) and at refrigeration temperature (4°C) for up to 21 days. The results, indicated that, there was a significant increase ($P < 0.05$) in lycopene of coated stored tomatoes.

The control samples which were dipped in distilled water and stored in room or refrigeration storage had lycopene value of 4.82 and 9.5 on day 7 and 14 respectively. While the control samples which were brushed in distilled water and stored at room or refrigeration temperature had the lycopene value of 4.71 and 7.01 on day 7 and 14 respectively.

For Cassava starch coating, the samples which were dipped in 3% CS and stored at room temperature (28°C) showed the high lycopene value (19.96) than 1 & 2% on day 7 while the samples which were dipped in 1% CS and stored in refrigeration had the high lycopene value of 35.16 than 2 & 3% on day 21. However, the samples which were brushed in 2% CS and stored in room or refrigeration, showed the lycopene value of (52.97) and (29.64) on day 21 respectively.

For citric acid coating, the samples which were dipped in 0.5% CA and stored at room temperature (28°C) or at refrigeration (4°C) showed the lycopene value of (73.8) and 25.5 on day 21. However, the samples brushed in 0.5% CA and stored at room temperature or refrigeration temperature showed the high lycopene value of 70.87 and 56.41 than 1% CA on day 21 respectively.

For Cassava starch mixed with citric acid, the samples which were dipped in 3:1 CS+CA and stored at room temperature showed the high lycopene value (86.34) than other combinations on day 21, while the samples dipped in 3:0.5 CS+CA and stored at refrigeration temperature(4°C) showed the high lycopene value of 67.45 than other on day 21. However, the samples brushed in 1:1 CS+CA and stored at room temperature or refrigeration (4°C) showed the high lycopene value of 74.23 and 45.59 than other combinations on day 21 respectively.

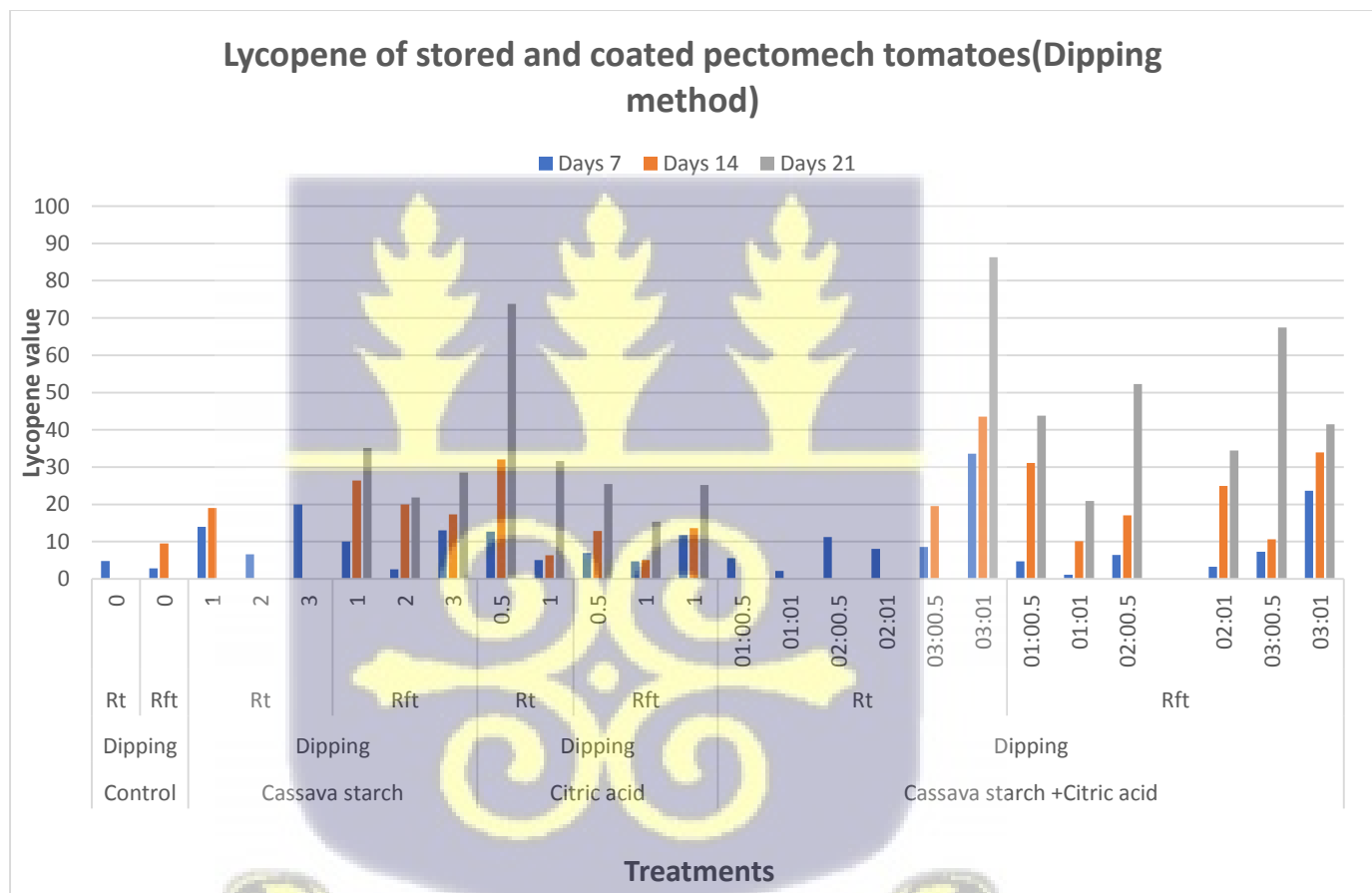


Figure 4.5: Effect of edible coatings on lycopene of tomatoes stored at room temperature (28°C) and in Refrigeration (4°C) with dipping method

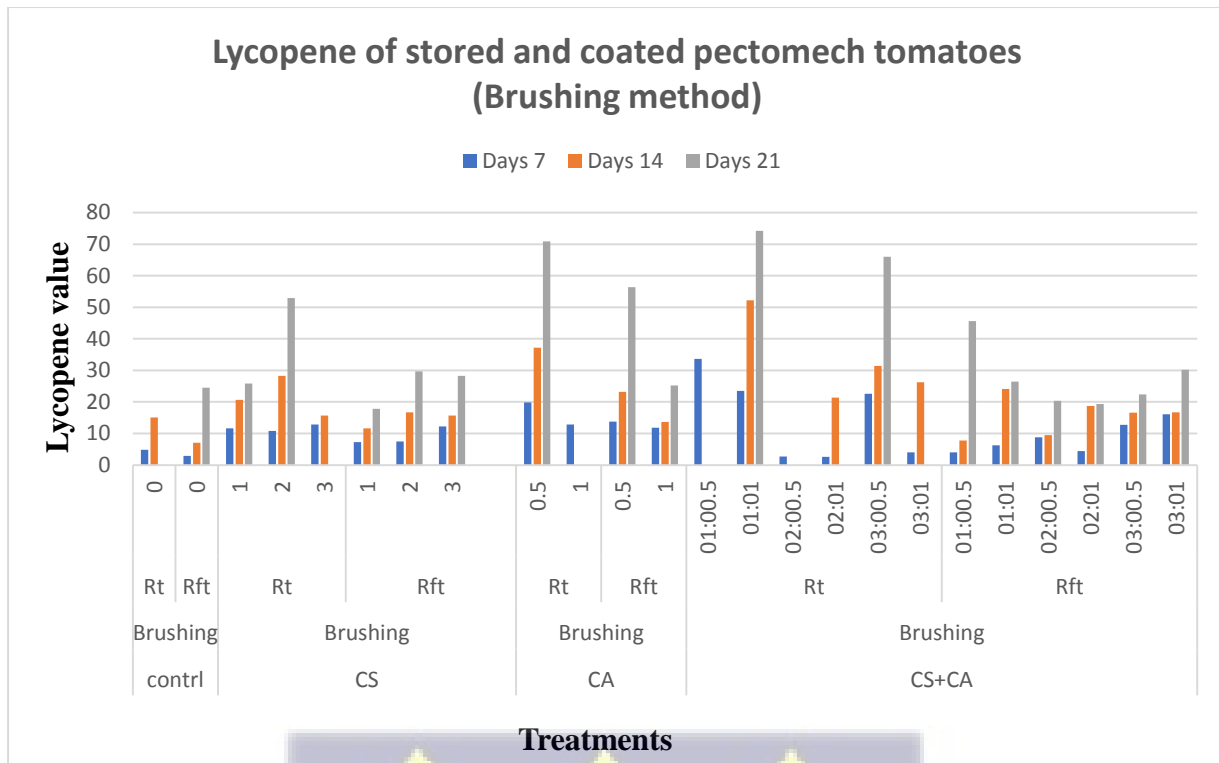


Figure 4.6: Effect of edible coatings on lycopene of tomatoes stored at room temperature and in refrigeration with brushing method

4.1.6 Effect of edible coatings on potential of Hydrogen (pH) of tomatoes stored at room temperature and at refrigeration

Table 4.3 (a,b) shows the changes in pH of pectomech tomatoes coated with different edible coatings and stored at room temperature (28°C) and refrigeration temperature (4°C) for up to 21 days. The results, indicated that, there was a significant increase ($P < 0.05$) in pH value of stored tomatoes.

From the results, the control samples which were dipped in distilled water and stored at room temperature (28°C) or at refrigeration (4°C) had the pH value of 5.09 and 5.03 on day 7 respectively, whereas samples which were brushed in distilled and stored at room temperature (28°C) or at refrigeration temperature (4°C) had the pH value of 5.05 and 4.84 on day 14 respectively.

For cassava starch coating, the samples which were dipped in 1% CS and stored at room temperature (28°C) or at refrigeration (4°C) had the pH value of 5.12 and 4.80 on day 14 respectively, whereas the samples which were stored at refrigeration temperature (4°C) and dipped in 2% or 3% CS had the pH value of 4.82 and 4.76 on day 21 respectively.

However the samples which were brushed in 1% CS and stored at room temperature (28°C) or at refrigeration (4°C) had the pH value of 5.03 and 4.86 on day 21 respectively, while the samples which were brushed in 2% CS and stored at room temperature (28°C) or at refrigeration temperature (4°C) had the pH value of 5.29 and 4.71 on day 21 respectively.

For citric acid coating, the samples which were dipped in citric acid 0.5% CA and stored at room temperature (28°C) or at refrigeration (4°C) had the pH value of 5.23 and 5.03 on day 21 respectively, whereas the samples which were dipped in 1% CA and stored at room temperature (28°C) or at refrigeration temperature (4°C) had the pH value of 4.92 and 4.95 on day 21 respectively. However, the samples which were stored in refrigeration (4°C) and brushed in 0.5% or 1% CA had the pH value of 5.32 and 4.84 on day 21 respectively.

For cassava starch combined with citric acid coating, the samples which were dipped in cassava starch mixed with citric acid (3:0.5% CS+CA) and stored at room temperature(28°C) or at refrigeration(4°C) had the pH value of 4.76 and 4.85 on day 21 respectively, whereas the samples which were dipped in (3:1% CS+CA) and stored at room temperature(28°C) or at refrigeration temperature(4°C) had the pH value of 4.99 and 4.95 on day 21 respectively. However the samples which were brushed in 3:0.5% CS+CA and stored at room temperature (28°C) or at refrigeration (4°C) had the pH value of 5.05 and 4.87 on day 21 respectively, while the samples which were brushed in (2:05 and 3:1% CS+CA) and stored at refrigeration temperature (4°C) had the pH value of 4.13 and 4.81 on day 21 respectively.

Table 4.3(a). Effect of edible coatings on potential of hydrogen pH of tomatoes stored at room temperature and at refrigeration

Coating material	Method of application	Storage place	%		Days			
					0	7	14	21
Control	Dipping	Rt			5.00b	5.09def	N/A	N/A
		Rft			4.70b	5.03d	5.03c	N/A
	Brushing	Rt			5.01cdef	5.02c	5.05cde	N/A
		Rft			4.72bc	4.53b	4.84cd	5.09b
Cassava starch	Dipping	Rt	1		4.61b	4.96bcdef	5.12de	N/A
			2		4.62bcd	N/A	N/A	N/A
			3		5.09b	4.82cd	N/A	N/A
		Rft	1		4.50abc	4.68bc	4.80b	N/A
			2		4.88b	3.79a	4.63abcd	4.82abc
			3		4.54abc	4.72bcd	4.58bc	4.76b
	Brushing	Rt	1	pH	4.67bcd	4.94b	5.03cde	5.03c
			2		4.89b	4.89abcde	4.90abc	5.29f
			3		4.96b	4.96bcdef	N/A	N/A
		Rft	1		4.70cd	4.40ab	4.43ab	4.86b
			2		4.59bcd	4.59bc	4.65b	4.71b
			3		4.54bc	4.50b	4.67cd	N/A
Citric acid	Dipping	Rt	0.5		4.70b	4.85abcde	4.91abc	5.23ef
			1		4.68bcd	4.45a	5.52d	4.92b
		Frg	0.5		4.61b	3.97a	4.59ab	5.03d
			1		4.68b	4.77cd	4.86bc	4.95b
			1		4.98b	4.51ab	5.03cdef	N/A
	Brushing	Rt	0.5		4.88	N/A	N/A	N/A
			1		4.51bc	4.59b	4.94cd	5.32e
		Rft	0.5		4.53abc	4.63b	4.64bc	4.84b

Data are presented as means \pm SD. Means within a column with different letters are significantly different at $P \leq 0.05$

Note: N/A: Not Applicable; measurement was not taken because tomatoes were already spoiled; TSS: total soluble solid; Rt: Room temperature (28°C); Rft: Refrigeration temperature (4°C)

Table 4.3(b). Effect of edible coatings on the pH of tomatoes stored at room temperature and at refrigeration

Coating material	Method of application	Storage place	Ratio	Days				
				0	7	14	21	
Cassava starch+Citric acid	Dipping	Rt	1:0.5	4.69b	4.49a	N/A	N/A	
			1:1	4.55b	4.72b	5.01bcde	N/A	
			2:0.5	4.58a	4.87bcdef	N/A	N/A	
			2:1	4.56b	4.60abc	4.80bcde	N/A	
			3:0.5	4.54b	4.65abcd	6.68e	4.76b	
			3:1	4.74abcd	4.85c	4.95bcdef	4.99bc	
			Rft	1:0.5	4.54abc	4.47b	4.52ab	4.94bcdef
				1:1	4.53b	4.65bc	4.80cd	4.46a
				2:0.5	4.51abc	4.62b	4.99bcde	4.80abc
				2:1	4.50b	4.70cd	5.01c	N/A

		3:0.5	4.44ab	4.15ab	4.74bc	4.85b
		3:1	4.48b	4.60bcd	4.63b	4.95bc
Brushing	Rt	1:0.5	4.94b	N/A	N/A	N/A
		1:1	4.60b	4.79abcd	4.99bc	4.89bcdef
		2:0.5	4.65b	N/A	N/A	N/A
		2:1	4.60bc	4.55abc	N/A	N/A
		3:0.5	4.90abcde	4.93bcdef	5.11b	5.05c
		3:1	4.76b	4.65abcd	4.72abc	N/A
	Rft	1:0.5	4.14a	4.58bc	4.60b	4.81b
1:1		4.52bc	4.57b	4.73b	4.92cd	
2:0.5		4.59bcd	4.53b	4.56bc	4.13a	
2:1		4.60bcd	4.85b	4.93b	4.95abc	
3:0.5		4.69cd	4.59ab	4.82bc	4.87a	
3:1		4.76bc	4.91cd	4.98b	4.81bcde	

Data are presented as means \pm SD. Means within a column with different letters are significantly different at $P \leq 0.05$

Note: N/A: Not Applicable; measurement was not taken because tomatoes were already spoilt; TSS: total soluble solid; Rt: Room temperature (28°C); Rft: Refrigeration temperature (4°C).

4.1.7. Effect of edible coatings on the Vitamin c of tomatoes stored at room temperature and refrigeration.

Figure 4.7 and 4.8 show the changes in Vitamin c of pectomech tomatoes coated with different edible coatings by dipping and brushing methods and stored at room temperature (28°C) and refrigeration temperature (4°C) for up to 21 days. The results, indicated that, there was a significant decrease ($P < 0.05$) in Vit.c value of stored tomatoes.

From the results, the control samples which were dipped in distilled and stored at room or at refrigeration temperatures showed the vitamin c values of 7.2 and 7.15 on day 7 and 14 respectively, while the samples which were brushed with distilled water and stored at room or refrigeration temperatures had the vitamin c value of 6.95 and 7.72 on day 14 respectively.

For cassava starch coating, the samples which were dipped in 2% CS stored at room (28°C) or at refrigeration temperature (4°C) showed the Vitamin c values of 7.21 and 6.94 than 1 & 3% CS on day 7 and 21 respectively, Again the samples which were brushed in 2% CS and stored

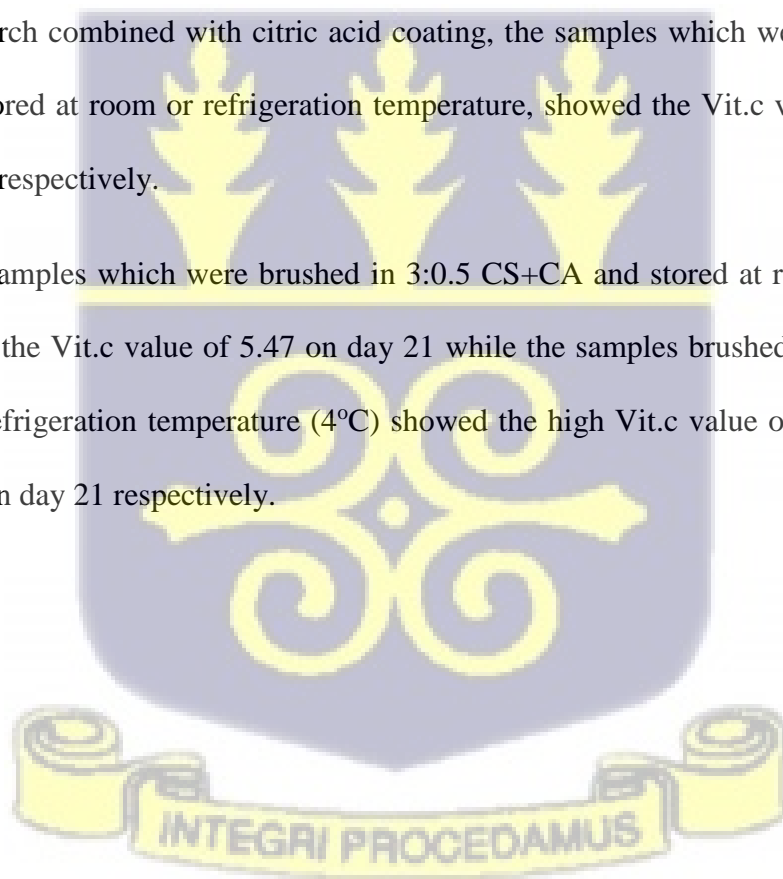
at room or refrigeration temperature (4°C) showed the high Vitamin c value of 6.8 and 6.94 than 1 & 3% CS on day 21 respectively.

For citric acid coating, the samples which were dipped in 0.5 % CA and stored at room temperature (28°C) showed the Vit.c value of 6.54 on day 21 and samples which were dipped in 1% CA and stored at refrigeration temperature (4°C) showed the high vitamin c value of 6.58 than Vitamin c of samples dipped in 0.5 % CA.

However, the samples which were brushed in 0.5 % CA and stored at room temperature (28°C) had the Vitamin c value of 6.94 on day 21 while the samples brushed in 1% CA and stored at refrigeration temperature (4°C) showed the Vit.c value of 8.65 on day 21 respectively.

For cassava starch combined with citric acid coating, the samples which were dipped in 3:1 CS+CA and stored at room or refrigeration temperature, showed the Vit.c value of 8.85 and 9.42 on day 21 respectively.

However, the samples which were brushed in 3:0.5 CS+CA and stored at room temperature (28°C) showed the Vit.c value of 5.47 on day 21 while the samples brushed in 2:0.5 CS+CA and stored at refrigeration temperature (4°C) showed the high Vit.c value of 9.67 than other combinations on day 21 respectively.



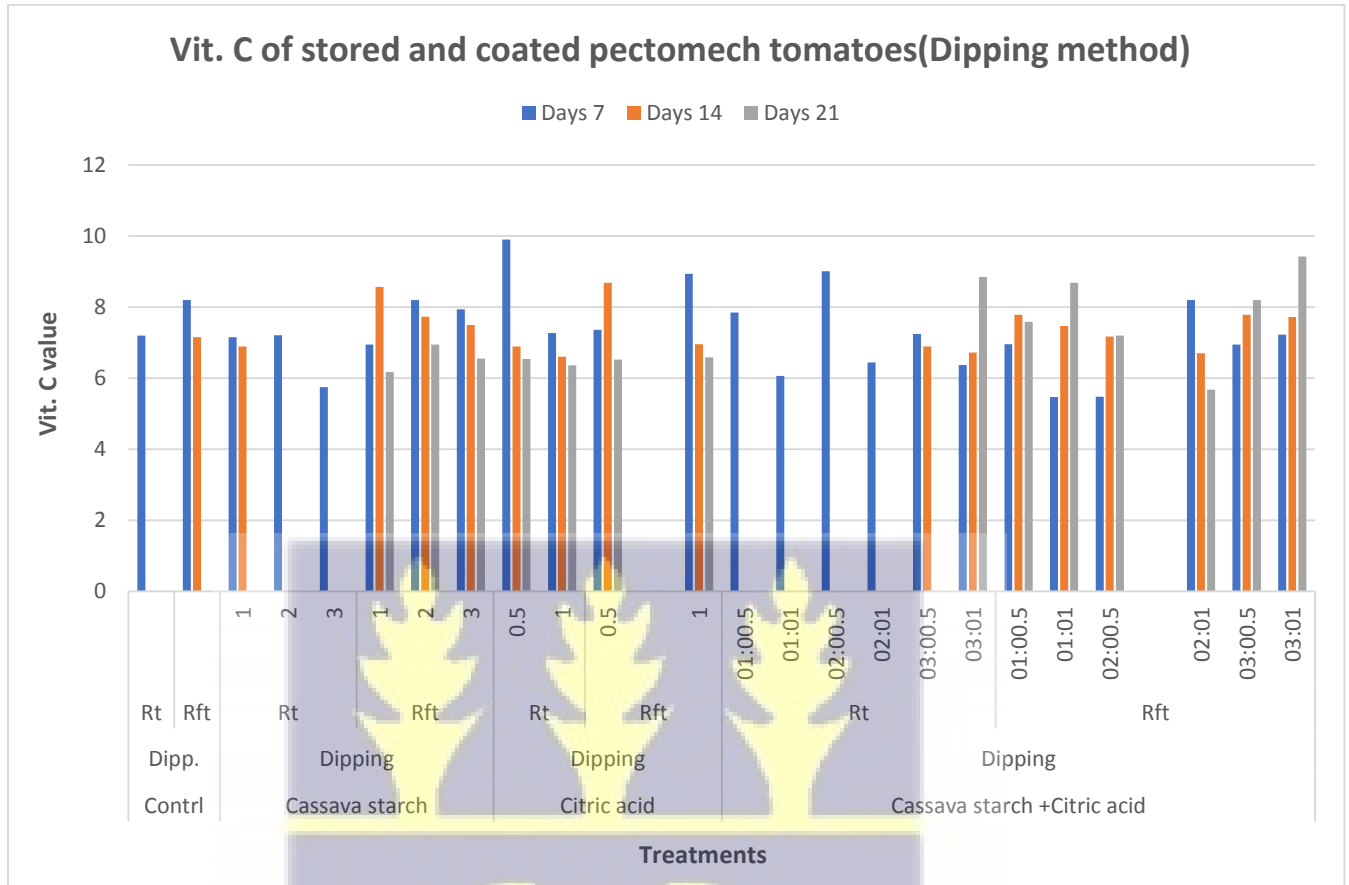
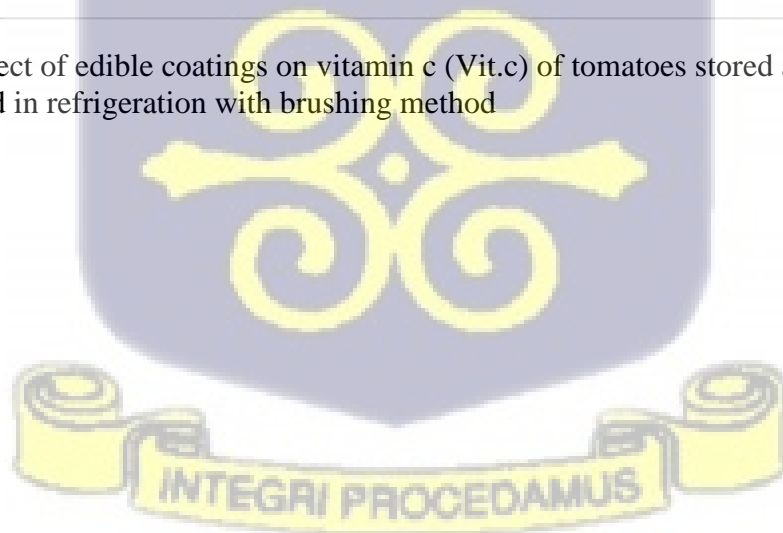


Figure 4.7: Effect of edible coatings on vitamin c (Vit.c) of tomatoes stored at room temperature and in refrigeration with brushing method



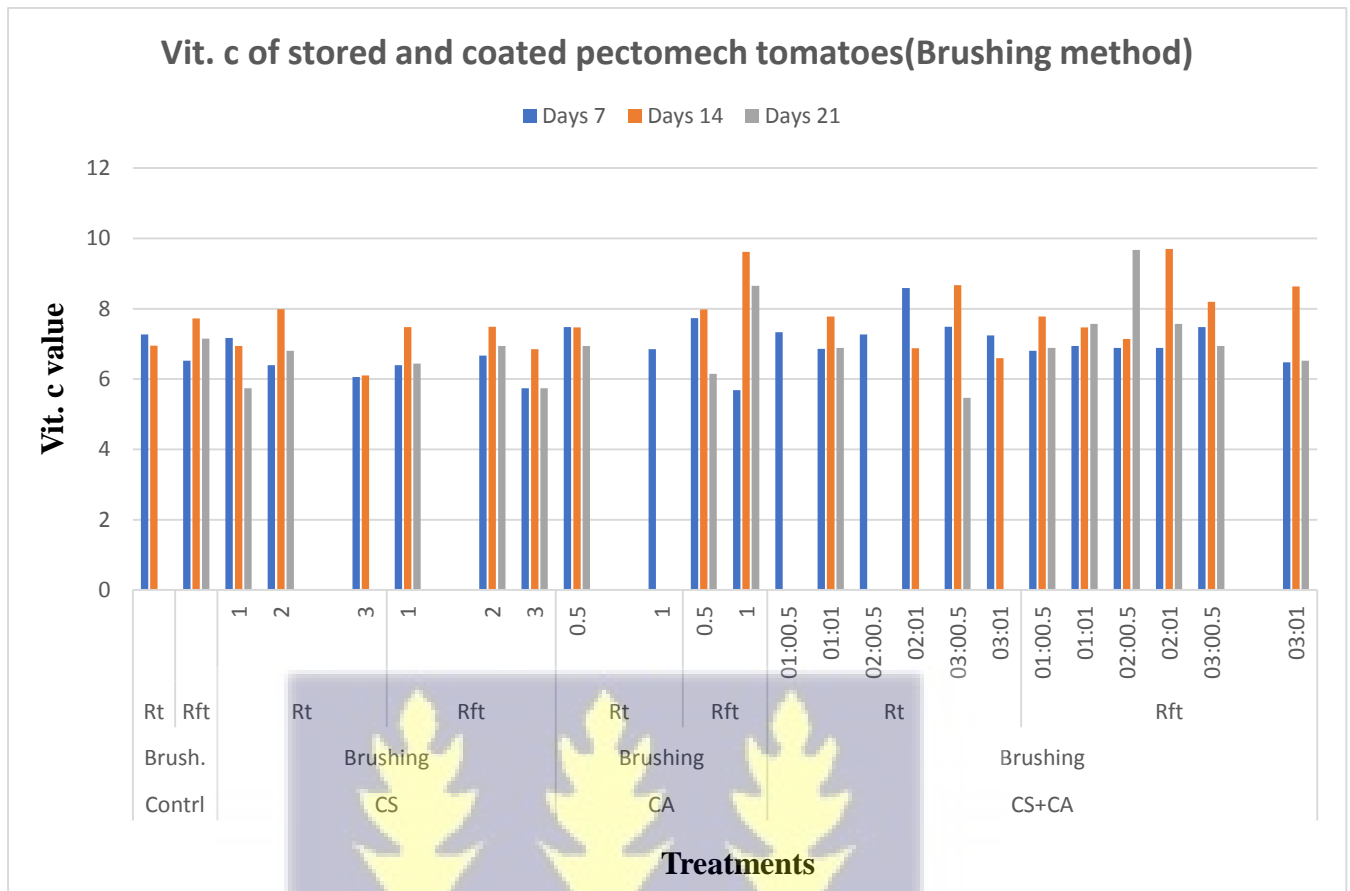


Figure 4.8: Effect of edible coatings on Vit.c of tomatoes stored at room temperature and in refrigeration with brushing method

4.1.8. Effect of edible coatings on titratable acidity (TA) of tomatoes stored at room temperature and refrigeration

Table 4.4 (a, b) shows the changes in titratable acidity (TA) of pectomech tomatoes coated with different edible coatings and stored at room temperature (28°C) and refrigeration temperature (4°C) for up to 21days. The results, indicated that, there was a significant decrease ($P < 0.05$) in TA value during storage of tomatoes.

From the results, it was observed that the control samples which were dipped in distilled water and stored at room temperature (28°C) or at refrigeration (4°C) had the TA value of 2.23 and 4.58 on day 7 respectively, whereas the samples which were brushed in distilled water and

stored at room temperature (28°C) or at refrigeration temperature (4°C) had the TA value of 1.98 and 3.53 on day 14 and 21 respectively.

For cassava starch coating, the samples which were dipped in 1% CS and stored at room temperature (28°C) or at refrigeration (4°C) had the TA value of 1.64 and 3.71 on day 14 respectively, whereas the samples which were brushed in 3% CS and stored in refrigeration temperature (4°C) had the TA value of 3.40 on day 21. However, the samples which were brushed in 1% CS and stored at room temperature (28°C) or at refrigeration (4°C) had the TA value of 1.75 and 2.46 on day 21 respectively, while the samples which were brushed in 2% CS and stored at room temperature (28°C) or at refrigeration temperature (4°C) had the TA value of 2.72 and 3.72 on day 21 respectively.

For citric acid coating, the samples which were dipped in citric acid (0.5% CA) and stored at room temperature (28°C) or at refrigeration (4°C) had the TA value of 1.88 and 3.94 on day 21 respectively, whereas the samples which were dipped in 1% CA and stored at room temperature (28°C) or at refrigeration temperature (4°C) had the TA value of 2.82 and 2.17 on day 21 respectively. However, the samples which were brushed in 0.5% CA and stored at room temperature (28°C) or at refrigeration (4°C) had the TA value of 2.75 and 2.12 on day 14 and 21, while the samples which were brushed in 1% CA and stored in refrigeration (4°C) had the TA value of 3.19 on day 21.

For cassava starch mixed with citric acid coating, the samples which were dipped in cassava starch mixed with citric acid (1:1% CS+CA) and stored at room temperature (28°C) or at refrigeration (4°C) had the TA value of 3.45 and 2.88 on day 14 and 21 respectively. The samples which were dipped in (3:0.5% CS+CA) and stored at room temperature (28°C) or at refrigeration temperature (4°C) had the TA value of 2.94 and 2.69 on day 21 respectively.

However, the samples which were brushed in 1:1% CS+CA and stored at room temperature (28°C) or in refrigeration (4°C) had the TA value of 2.88 and 2.46 on day 21 respectively while the samples which were brushed in (3:0.5% CS+CA) and stored at room temperature (28°C) or at refrigeration temperature (4°C) had the TA value of 2.23 and 3.59 on day 21 respectively.

Table 4.4(a). Effect of edible coatings on Titratable acidity (TA) of tomatoes stored at room temperature and in refrigeration

Coating material	Method of application	Storage place	%	Days			
				0	7	14	21
Control	Dipping	Rt		4.63bc	2.23abc	N/A	N/A
		Rft		4.37b	4.58g	2.25a	N/A
	Brushing	Rt		4.75bc	2.17ab	1.98ab	N/A
		Rft		4.10b	6.90k	3.58bc	3.53ef
Cassava starch	Dipping	Rt	1	4.59bc	2.64bcd	1.64a	N/A
			2	4.41b	N/A	N/A	N/A
			3	5.42d	4.74gh	N/A	N/A
	Brushing	Rft	1	4.42b	4.10f	3.71bcd	N/A
			2	4.82c	5.82i	3.95gh	N/A
			3	5.82f	4.40ef	4.13cd	3.40e
		Rt	1	4.88cd	3.13ef	1.81a	1.75a
			2	5.41b	3.76f	2.75cd	2.72bc
			3	4.55bc	2.17ab	N/A	N/A
		Rft	1	4.13b	5.47h	3.75bc	2.46ab
			2	4.82c	4.13de	3.93f	3.72bc
			3	4.66bc	9.13l	3.76bcd	N/A
Citric acid	Dipping	Rt	0.5	4.78bc	4.12gh	3.89f	1.88a
			1	3.95a	3.12de	2.94bcd	2.82bcd
			Rft	0.5	4.40b	5.13e	4.89gh
	Brushing	Rt	1	4.70bc	4.95e	3.12b	2.17a
			0.5	4.16b	2.94cd	2.75de	2.12ab
			1	4.98cd	N/A	N/A	N/A
Rft	0.5	3.9a	3.13de	3.11b	N/A		
1	5.37d	4.95gh	4.13de	3.19a			



Table 4.4(b). Effect of edible coatings on titratable acidity (TA) of tomatoes stored at room temperature and in refrigeration

Coating material	Method of application	Storage place	Ratio	Days				
				0	7	14	21	
Cassava starch +Citric acid	Dipping	Rt	1:0.5	4.42b	6.48j	N/A	N/A	
			1:1	4.77bc	3.95cde	3.45b	N/A	
			2:0.5	5.73e	5.47h	N/A	N/A	
			2:1	5.82f	4.12gh	3.37f	N/A	
			3:0.5	5.45de	3.88g	3.53de	2.94cd	
		3:1	4.42b	4.42h	3.15de	2.45b		
		Rft	1:0.5	3.94a	2.88bcd	2.80d	2.17bc	
			1:1	4.70bc	4.89i	4.39gh	2.88bcd	
			2:0.5	3.87ab	2.88de	1.88a	1.75a	
			2:1	5.41de	5.13h	2.23a	N/A	
	3:0.5		4.89cd	4.42d	3.42b	2.69bc		
	Brushing	Rt	1:0.5	TA	4.11b	N/A	N/A	N/A
			1:1	3.99a	3.48ef	3.28de	2.88bcd	
			2:0.5	4.92cd	N/A	N/A	N/A	
			2:1	4.08ab	3.90fg	N/A	N/A	
			3:0.5	5.48de	2.94cd	2.88d	2.23bc	
		Rft	1:0.5	4.80cd	3.89cd	3.47e	3.46ab	
			1:1	4.93cd	4.13cd	3.13de	2.46a	
			2:0.5	4.88cd	4.59fg	4.42cd	3.47ab	
			2:1	4.41b	2.94cd	2.81bcd	2.63cd	
3:0.5			4.94cd	4.13cd	3.93f	3.59bc		
		3:1	4.66bc	4.37ef	2.46ab	2.31ab		

Data are presented as means±SD. Means within a column with different letters are significantly different at P≤0.05

Note: N/A: Not Applicable; measurement was not taken because tomatoes were already spoiled, TA: Titratable acidity; Rt: Room temperature (28°C); Rft: Refrigeration temperature (4°C).



4.2. Experiment Two

The following results are for the tomato samples which showed desired quality in the 1st experiment. These coated samples comprising pectomech and wosowoso tomatoes varieties

were taken in the 2nd experiment to check their quality when packed in polyethylene and plastic bags and kept at room and refrigeration temperatures.

4.2.1. Effects of packaging materials on shelf-life of coated varieties of tomatoes stored at room temperature and at refrigeration

Figure 4.9 shows the changes in shelf life of two varieties of tomato (pectomech and wosowoso) coated with cassava starch mixed with citric acid (3:1), packed in polyethylene or baskets and stored at room temperature (28°C) or refrigeration temperature (4°C) for up to 35 days. The shelf life was significantly increased ($P < 0.05$) for all stored coated and packed tomato samples.

From the results, the control pectomech samples (coated but non-packed tomatoes) which were stored at room temperature (28°C) and in refrigeration temperature (4°C) had a shelf life of 14 and 30 days respectively, whereas for control wosowoso samples, which were stored at room temperature (28°C) and at refrigeration temperature (4°C) had the shelf life of 7 and 21 days respectively.

The pectomech samples which were packed in polyethylene bags and stored at room temperature (28°C) or at refrigeration temperature (4°C) had the shelf life of 20 days and 33 days respectively, while wosowoso samples packed in polyethylene bags and stored at room temperature (28°C) or at refrigeration temperature (4°C) had the shelf life of 9 and 23 days respectively.

For the pectomech samples which were packed in baskets and stored at room temperature (28°C) or at refrigeration temperature (4°C) had the shelf life of 22 days and 33 days while wosowoso samples which were packed in baskets and stored at room temperature (28°C) or at refrigeration temperature (4°C) had the shelf life of 12 and 25 days respectively.

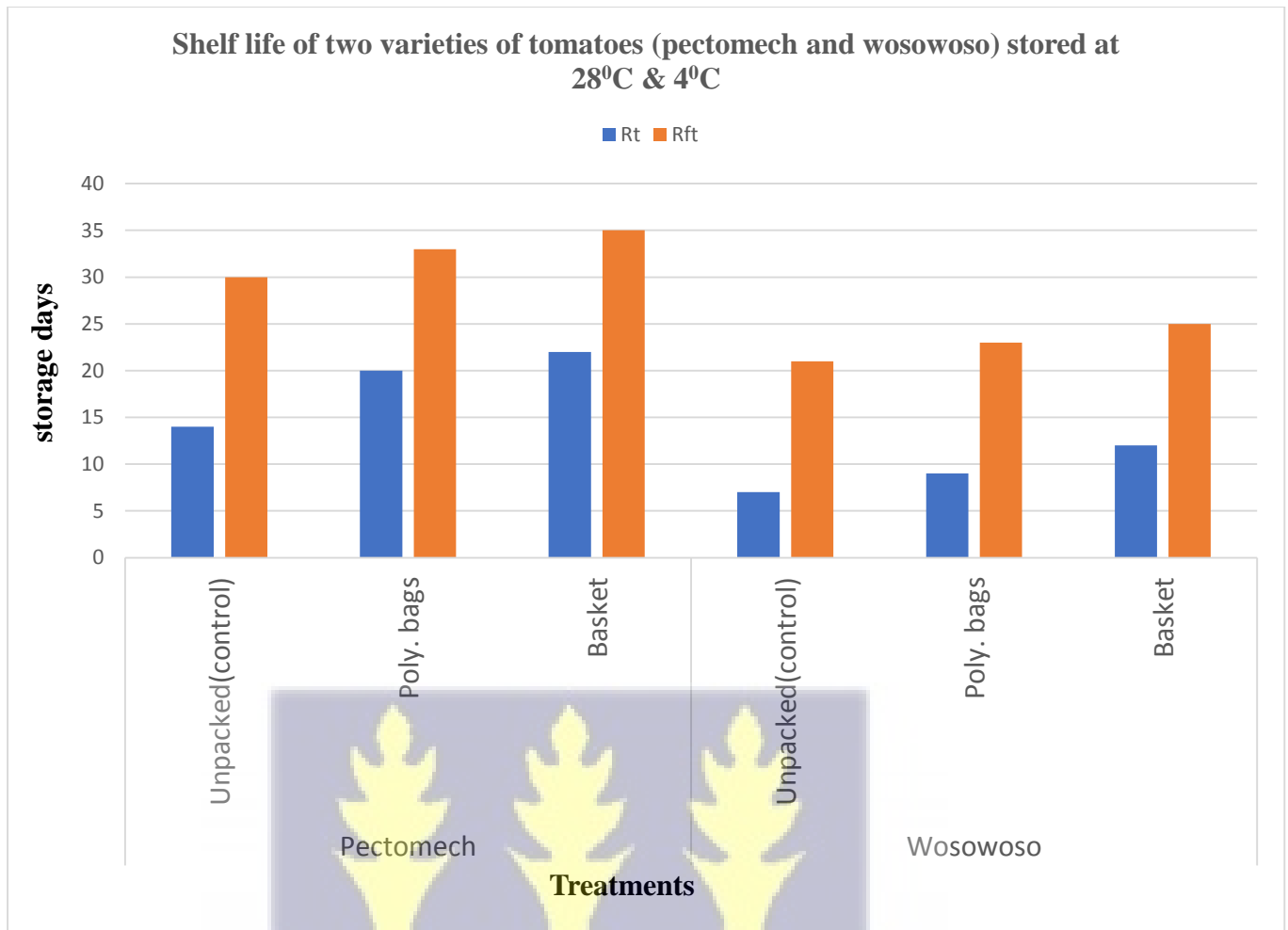


Figure 4.9: Effects of packaging material on shelf-life of coated tomato varieties (pectomech and wosowoso) stored at room temperature (28°C) and in refrigeration temperature (4°C).

4.2.2. Effects of packaging material on weight loss of coated varieties of tomatoes stored at room temperature and refrigeration

Figure 4.10 shows the changes in weight loss of pectomech and wosowoso tomatoes coated with cassava starch mixed with citric acid (3:1), packed in polyethylene or baskets and stored at room temperature (28°C) and refrigeration temperature (4°C) for up to 35 days. The weight loss was significantly increased with storage time ($P < 0.05$) for all stored coated and packed tomato samples.

From the results, it was observed that, the control pectomech or wosowoso samples (non-packed samples), which were stored at room temperature (28°C) had a weight loss of 4.75%

and 8.19 on day 7 respectively, while the control pectomech or wosowoso samples which were stored in refrigeration temperature(4°C) had a weight loss of 39.36% and 29.86% on day 21 respectively.

The pectomech or wosowoso samples which were packed in polyethylene bag and stored at room temperature (28°C) had a weight loss of 1.06% and 2.32% on day 7 respectively, while the pectomech or wosowoso samples which were packed in polyethylene bag and stored in refrigeration temperature (4°C) had a weight loss of 21.15% and 25.4% on day 21 respectively.

The pectomech or wosowoso samples which were packed in baskets and stored at room temperature (28°C) had a weight loss of 3.16% and 4.69% on day 7 respectively, while the pectomech or wosowoso samples which were packed in baskets and stored in refrigeration temperature (4°C) had a weight loss of 35.75% and 29.02% on day 21 respectively.

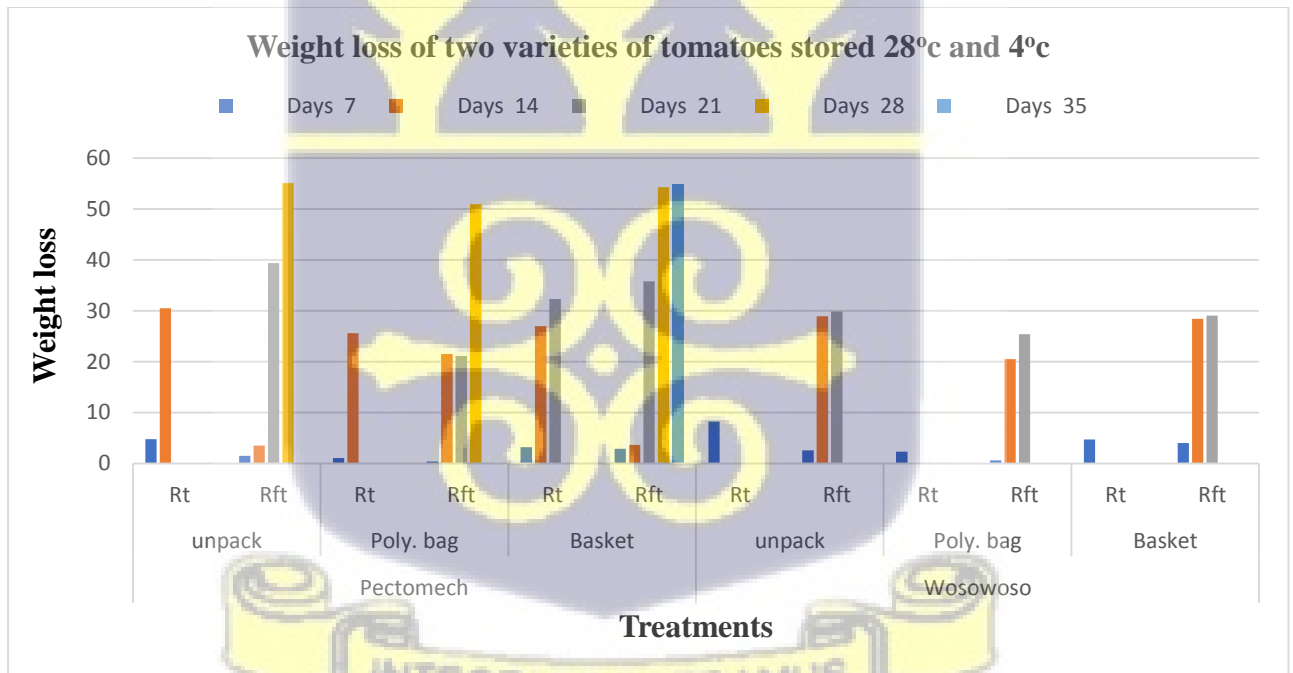


Figure 4.10. Effects of packaging material on weight loss of coated tomato varieties stored at room temperature and in refrigeration temperature; Rt: Room temperature (28°C); Rft: refrigeration temperature (4°C).

4.2.3 Effects of packaging materials on lycopene of coated tomato varieties stored at room temperature and at refrigeration

Table 4.5 shows the changes in lycopene value of pectomech and wosowoso tomatoes coated with cassava starch mixed with citric acid (3:1), packed in polyethylene or baskets and stored at room temperature (28°C) and refrigeration temperature (4°C) for up to 21 days. The lycopene value was significantly increased with storage time ($P < 0.05$) for all stored coated and packed tomato samples.

From the results, it was observed that the control pectomech or wosowoso samples (non-packed samples), which were stored at room temperature (28°C) had a lycopene value of 5.18 and 14.63 on day 7 respectively, while the control pectomech or wosowoso samples which were stored at refrigeration temperature (4°C) had the lycopene value of 22.91 and 21.81 on day 21 respectively.

The pectomech or wosowoso samples which were packed in polyethylene bags and stored at room temperature (28°C) had the lycopene value of 5.43 and 16.27 on day 7 respectively, while the pectomech or wosowoso samples which were packed in polyethylene bags and stored at refrigeration temperature (4°C) had the lycopene value of 26.30 and 21.09 on day 21 respectively.

The pectomech or wosowoso samples which were packed in baskets and stored at room temperature (28°C) had the lycopene value of 5 and 12.94 on day 7 respectively, while the pectomech or wosowoso samples which were packed in baskets and stored in refrigeration temperature (4°C) had the lycopene value of 11.55 and 16.43 on day 21 respectively.

Table 4.5. Effects of packaging material on lycopene of coated tomato varieties stored at room temperature and in refrigeration temperature

Variety	Packaging materials	Storage place	Days		
			7	14	21
Pectomech	Unpacked	Rt	5.18b	17.11c	N/A
		Rft	4.25a	6.54ab	22.91e
	Poly.bags	Rt	5.43b	31.77d	N/A
		Rft	4.37ab	7.65ab	26.30f
	Basket	Rt	5ab	5.59a	15.17b
		Rft	4.02a	4.86a	11.55a
Wosowoso	Unpacked	Rt	14.63d	N/A	N/A
		Rft	3.89a	7.19ab	21.81de
	Poly. bags	Rt	16.27e	N/A	N/A
		Rft	4.04a	8.84b	21.09d
	Basket	Rt	12.94c	N/A	N/A
		Rft	3.97a	8.29b	16.43c

Data are presented as means \pm SD. Means within a column with different letters are significantly different at $P \leq 0.05$

Note: N/A: Not Applicable; measurement was not taken because tomatoes were already spoilt;

TSS: Total soluble solid, Rt: Room temperature (28°C), Rft: Refrigeration temperature (4°C).

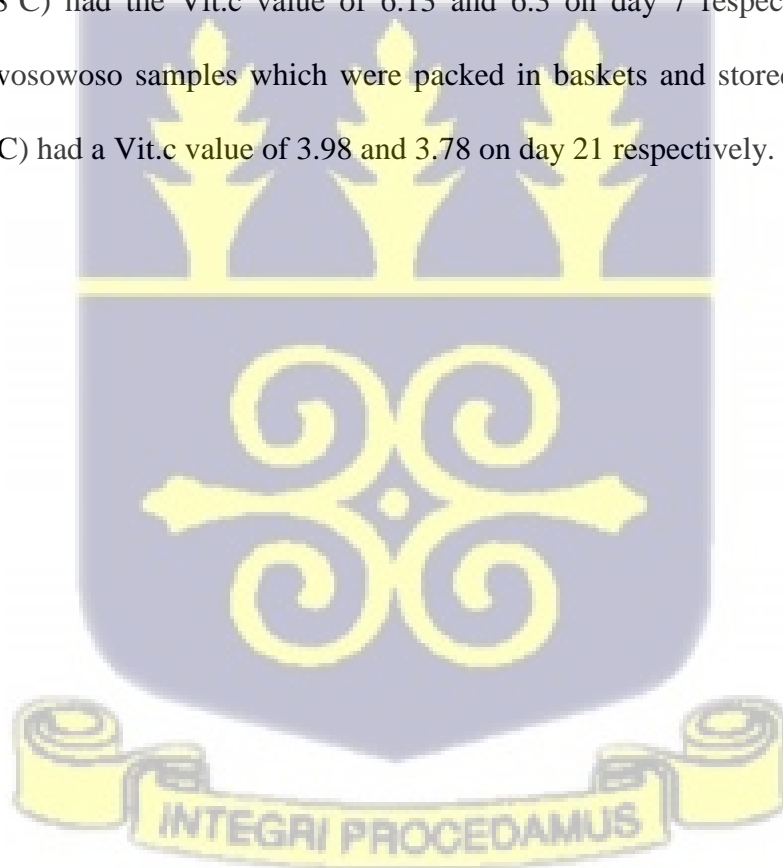
4.2.4 Effects of packaging material on Vitamin c of coated tomato varieties stored at room temperature and at refrigeration.

Figure 4.11 shows the changes in Vitamin c value of pectomech and wosowoso tomatoes coated with cassava starch mixed with citric acid (3:1), packed in polyethylene or baskets and stored at room temperature (28°C) and refrigeration temperature (4°C) for up to 21 days. The Vitamin c value was significantly decreased with storage time ($P < 0.05$) for all stored coated and packed tomato samples.

The control pectomech or wosowoso samples (non-packed samples), which were stored at room temperature (28°C) had a Vit.c value of 6.05 and 5.87 on day 7 respectively, while the control pectomech or wosowoso samples which were stored at refrigeration temperature (4°C) had the Vit.c value of 4.27 and 4 on day 21 respectively.

The pectomech or wosowoso samples which were packed in polyethylene bags and stored at room temperature (28°C) had the Vit.c value of 6.03 and 5.8 on day 7 respectively, while the pectomech or wosowoso samples which were packed in polyethylene bags and stored at refrigeration temperature (4°C) had the Vit.c value of 4.36 and 4 on day 21 respectively.

The pectomech or wosowoso samples which were packed in baskets and stored at room temperature (28°C) had the Vit.c value of 6.13 and 6.3 on day 7 respectively, while the pectomech or wosowoso samples which were packed in baskets and stored at refrigeration temperature (4°C) had a Vit.c value of 3.98 and 3.78 on day 21 respectively.



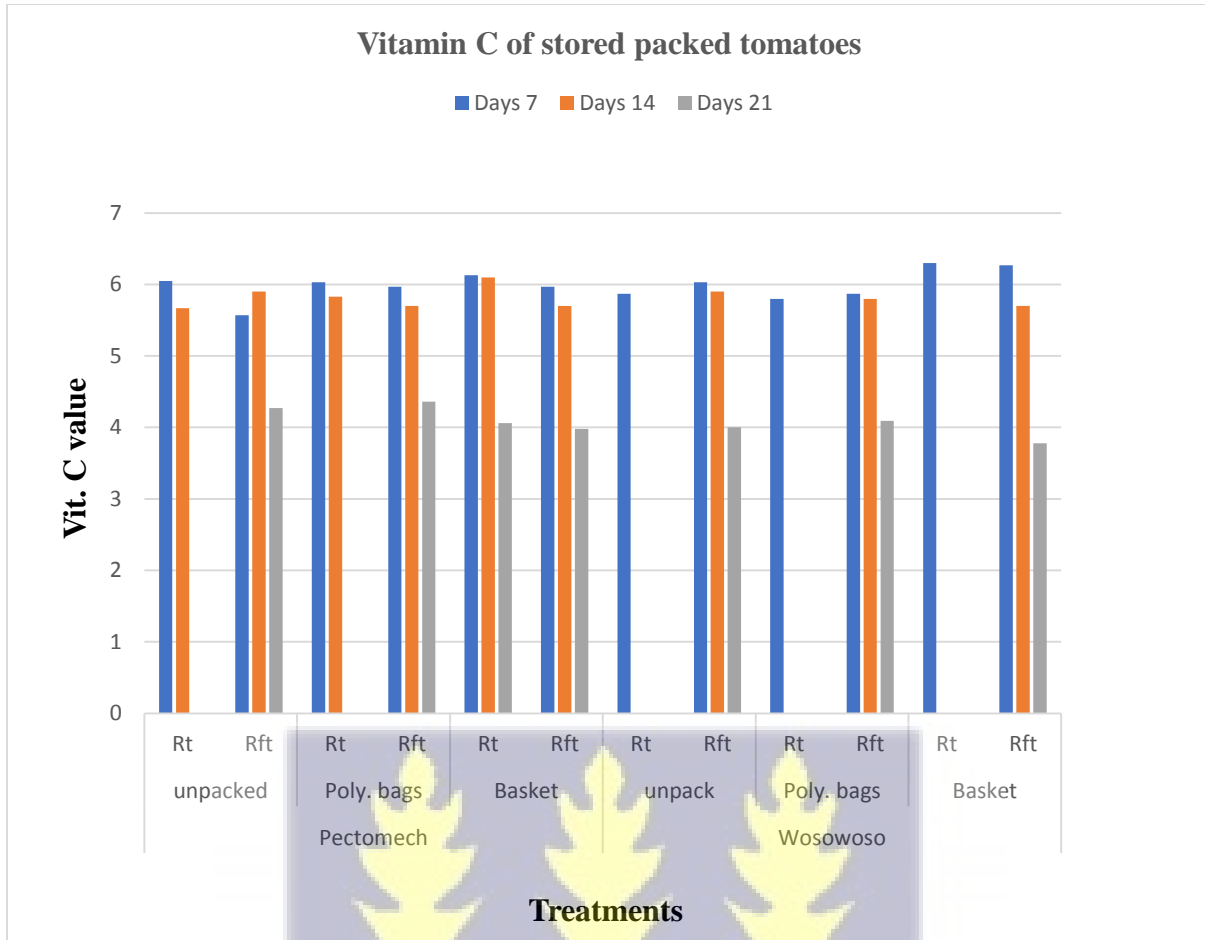


Figure 4.11: Effects of packaging material on Vit c of coated tomato varieties stored at room temperature and in refrigeration temperature

Note: Rt: Room temperature (28°C); Rft: refrigeration temperature (4°C).

4.2.5 Effects of packaging material on total soluble solids of coated tomato varieties stored at room temperature and at refrigeration

Table 4.6 shows the changes in total soluble solid (TSS) value of pectomech and wosowoso tomatoes coated with cassava starch mixed with citric acid (3:1), packed in polyethylene or baskets and stored at room temperature (28°C) or refrigeration temperature (4°C) for up to 28 days. The TSS value was significantly increased with storage time ($P < 0.05$) for all stored coated and packed tomato samples.

The control pectomech or wosowoso samples (non-packed samples), which were stored at room temperature (28°C) had the TSS value of 4.33 and 3.75 on day 7 respectively, while the

control pectomech or wosowoso samples which were stored in refrigeration temperature (4°C) had the TSS value of 3.80 and 5.05 on day 21 respectively.

The pectomech or wosowoso samples which were packed in polyethylene bags and stored at room temperature (28°C) had the TSS value of 3.85 and 3.75 on day 7 respectively, while the pectomech or wosowoso samples which were packed in polyethylene bags and stored at refrigeration temperature (4°C) had the TSS value of 4.35 and 5.10 on day 21 respectively.

The pectomech or wosowoso samples which were packed in baskets and stored at room temperature (28°C) had the TSS value of 3.50 and 4.23 on day 7 respectively, while the pectomech or wosowoso samples which were packed in baskets and stored at refrigeration temperature (4°C) had the TSS value of 4.80 and 4.40 on day 21 respectively.

Table 4.6. Effects of packaging material on total soluble solids of coated tomato varieties stored at room temperature and in refrigeration

Variety	Packaging materials	Storage place	Days				
			0	7	14	21	28
Pectomech	unpacked	Rt	3.27 a	4.33 c	4.50bc	N/A	N/A
		Rft	2.90a	3.00a	3.10a	3.80a	3.30a
	Poly. Bag	Rt	3.07a	3.85bc	4.37b	N/A	N/A
		Rft	3.07a	3.20a	4.20b	4.35b	4.40b
	Basket	Rt	3.40b	3.50b	4.73cd	4.96d	N/A
		Rft	TSS	3.45b	3.45b	4.60bc	4.80c
Wosowoso	Unpacked	Rt	3.50b	3.75bc	N/A	N/A	N/A
		Rft	3.40b	3.45b	5.00d	5.05d	N/A
	Poly. Bag	Rt	3.30a	3.50b	N/A	N/A	N/A
		Rft	3.00a	3.10a	4.80c	5.10d	N/A
	Baskets	Rt	3.95c	4.23c	N/A	N/A	N/A
		Rft	3.25a	4.15c	4.60bc	4.40b	N/A

Data are presented as means \pm SD. Means within a column with different letters are significantly different at $P \leq 0.05$

Note: N/A: Not Applicable as measurement was not taken because tomatoes were already spoilt;

TSS: Total soluble solid, Rt: Room temperature (28°C), Rft: Refrigeration temperature (4°C).

4.2.6 Effects of packaging material on potential of Hydrogen (pH) of coated tomato varieties stored at room temperature and at refrigeration.

Table 4.7 shows the changes in pH value of pectomech and wosowoso tomatoes coated with cassava starch mixed with citric acid (3:1), packed in polyethylene or baskets and stored at room temperature (28°C) and refrigeration temperature (4°C) for up to 28 days. The pH value was significantly increased with storage time ($P < 0.05$) for all stored coated and packed tomato samples. The control pectomech or wosowoso samples (non-packed samples), which were stored at room temperature (28°C) had the pH value of 4.57 and 4.89 on day 7 respectively, while the control pectomech or wosowoso samples which were stored at refrigeration temperature (4°C) had the pH value of 4.80 and 4.38 on day 21 respectively.

The pectomech or wosowoso samples which were stored at room temperature (28°C) and packed in polyethylene bags had the pH value of 4.60 and 4.67 on day 7 respectively, while the pectomech or wosowoso samples which were stored in refrigeration temperature (4°C) and packed in polyethylene bags had the pH value of 5.37 and 4.80 on day 21 respectively.

The pectomech or wosowoso samples which were packed in baskets and stored at room temperature (28°C) had the pH value of 4.60 and 5.09 on day 7 respectively, while the pectomech or wosowoso samples which were packed in baskets and stored at refrigeration temperature (4°C) had the pH value of 4.88 and 4.29 on day 21 respectively.

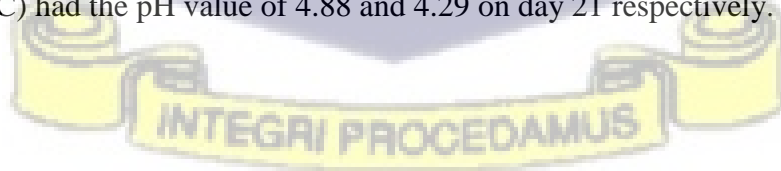


Table 4.7. Effects of packaging material on pH of coated tomato varieties stored at room temperature and in refrigeration

Variety	Packaging materials	Storage places	Days				
			0	7	14	21	28
Pectomech	Unpacked (Control)	Rt	4.22a	4.57b	4.83e	N/A	N/A
		Rft	4.26a	4.52b	4.72d	4.80b	6.21c
	Poly. Bag	Rt	4.41c	4.60c	4.46b	N/A	N/A
		Rft	4.41c	4.57b	5.02e	5.37c	6.12b
	Basket	Rt	4.25a	4.60c	4.60c	N/A	N/A
		Rft	pH	4.41b	5.18e	4.28a	4.88b
Wosowoso	Unpacked	Rt	4.58d	4.89d	N/A	N/A	N/A
		Rft	4.21a	4.29a	4.32a	4.38ab	N/A
	Poly. Bag	Rt	4.22a	4.67c	N/A	N/A	N/A
		Rft	4.18a	4.18a	4.51ab	4.80b	N/A
	Basket	Rt	4.34b	5.09de	N/A	N/A	N/A
		Rft	4.33b	4.38ab	4.51c	4.29a	N/A

Data are presented as means \pm SD. Means within a column with different letters are significantly different at $P \leq 0.05$

Notes: N/A: Not Applicable; measurement was not taken because tomatoes were already spoilt; Poly. bag: Polyethylene bag; Rt: Room temperature(28°C); Rft: refrigeration temperature(4°C).

4.2.7 Effects of packaging material on titratable acidity (TA) of coated tomato varieties stored at room temperature and at refrigeration

Table 4.8 shows the changes in titratable acidity (TA) value of pectomech and wosowoso tomatoes coated with cassava starch mixed with citric acid (3:1) packed in polyethylene or baskets and stored at room temperature (28°C) and refrigeration temperature (4°C) for up to 28 days. The TA value was significantly decreased with storage time ($P < 0.05$) for all stored coated and packed tomato samples.

The control pectomech or wosowoso samples (non-packed samples), which were stored at room temperature(28°C) had the TA value of 4.75 and 2.08 on day 7 respectively, while the

control pectomech or wosowoso samples which were stored at refrigeration temperature (4°C) had the TA value of 2.25 and 3.25 on day 21 respectively.

The pectomech or wosowoso samples which were packed in polyethylene bags and stored at room temperature (28°C) had the TA value of 2.88 and 3.50 on day 7 respectively, while the pectomech or wosowoso samples which were packed in polyethylene bags and stored at refrigeration temperature (4°C) had the TA value of 4.13 and 2.75 on day 21 respectively.

The pectomech or wosowoso samples which were packed in baskets and stored at room temperature (28°C) had the TA value of 3.00 and 1.75 on day 7 respectively, while the pectomech or wosowoso samples which were packed in baskets and stored at refrigeration temperature (4°C) had the TA value of 2.88 and 4.88 on day 21 respectively.

Table 4.8: Effects of packaging material on titratable acidity (TA) of coated tomato varieties stored at room temperature and in refrigeration

Variety	Packaging materials	Storage place	Days				
			0	7	14	21	28
Pectomech	Control (unpacked)	Rt	6.50f	4.75c	2.38a	N/A	N/A
		Rft	4.75b	3.06a	2.50ab	2.25a	1.63a
	Poly. Bag	Rt	5.50c	2.88a	2.6ab	N/A	N/A
		Rft	5.44d	4.63c	4.38c	4.13d	1.88ab
	Basket	Rt	4.29a	3.00b	2.04a	N/A	N/A
		Rft	TA	6.00e	3.88b	3.25b	2.88ab
Wosowoso	Unpacked	Rt	3.13a	2.08ab	N/A	N/A	N/A
		Rft	4.45b	4.45c	3.56b	3.25c	N/A
	Poly. Bag	Rt	3.88a	3.50c	N/A	N/A	N/A
		Rft	5.94c	5.50d	4.38c	2.75ab	N/A
	Basket	Rt	4.13b	1.75a	N/A	N/A	N/A
		Rft	6.75d	6.75e	5.75d	4.88d	N/A

Data are presented as means \pm SD. Means within a column with different letters are significantly different at $P\leq 0.05$

Notes: N/A: Not Applicable; measurement was not taken because tomatoes were already spoilt;

TA: titratable acidity; Poly.bag: Polyethylene bag; Rt: Room temperature (28°C); Rft: refrigeration temperature (4°C).

4.3 Sensory evaluation of tomato varieties following different packaging materials and storage places.

In order to get information on consumer acceptance of stored coated and packed tomatoes, the sensory was carried out on each sample used in experiment two, and the sensory attributes (appearance, texture, colour and overall acceptability) of samples stored at room(28°C) and refrigeration(4°C) were evaluated. Stored samples were evaluated for appearance, texture, colour and overall acceptability. Ten panellists from the Department of crop science at University of Ghana participated in the evaluation and assessed the samples using a 5-point intensity scale (scale of 1 to 5; 1 = disliked extremely; 2=disliked; 3= neither liked nor disliked; 4=liked and 5 = liked extremely).

In the result from figure 4.12, it was observed that packaging materials had significant effect on appearance, texture, colour, and overall acceptability.

For pectomech variety, in terms of appearance, tomato fruits samples packed in polyethylene bags and stored at room temperature (28°C) were most preferred by the panellist to control fruits (non-packed) and fruits packed in baskets whereas at refrigeration temperature, tomatoes packed in basket were preferred more than control and polyethylene samples.

The panellist judged fruits stored at room temperature (28°C) and packed in polyethylene bags to have high value of texture than control or samples packed in basket, while at refrigeration

temperature (4°C) the samples packed in basket were chosen more to have high value of texture than control and samples packed in polyethylene packaging.

The study also revealed that in terms of colour fruit samples packed in polyethylene bags and stored at room temperature(28°C) were accepted than other treatments (control and samples packed in baskets) while for the samples stored at refrigeration temperature the basket samples were preferred more than polyethylene samples and control.

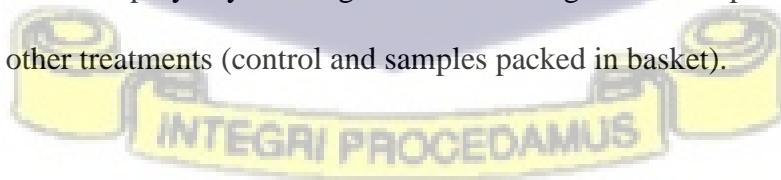
With respect to overall acceptability, samples stored at room temperature (4°C) and packed in polyethylene bags were most accepted by the panellists than control and samples packed in baskets, while in samples stored at refrigeration temperature the basket samples were chosen more than control and polyethylene samples.

For wosowoso variety, in terms of appearance, the control samples were accepted by majority of the panellist than packed samples either in polyethylene or baskets, while at refrigeration temperature storage, polyethylene samples were liked more than control and basket samples.

Similarly, the control samples stored at room (28°C) or refrigeration temperature (4°C) were accepted more in terms of texture than samples packed in basket or polyethylene bags.

The effect of packaging materials on colour was significantly higher in samples packed in polyethylene bags and stored at refrigeration (4°C) than control and samples packed in baskets.

Fruit samples packed in polyethylene bags stored at refrigeration temperature (4°C), were chosen over the other treatments (control and samples packed in basket).



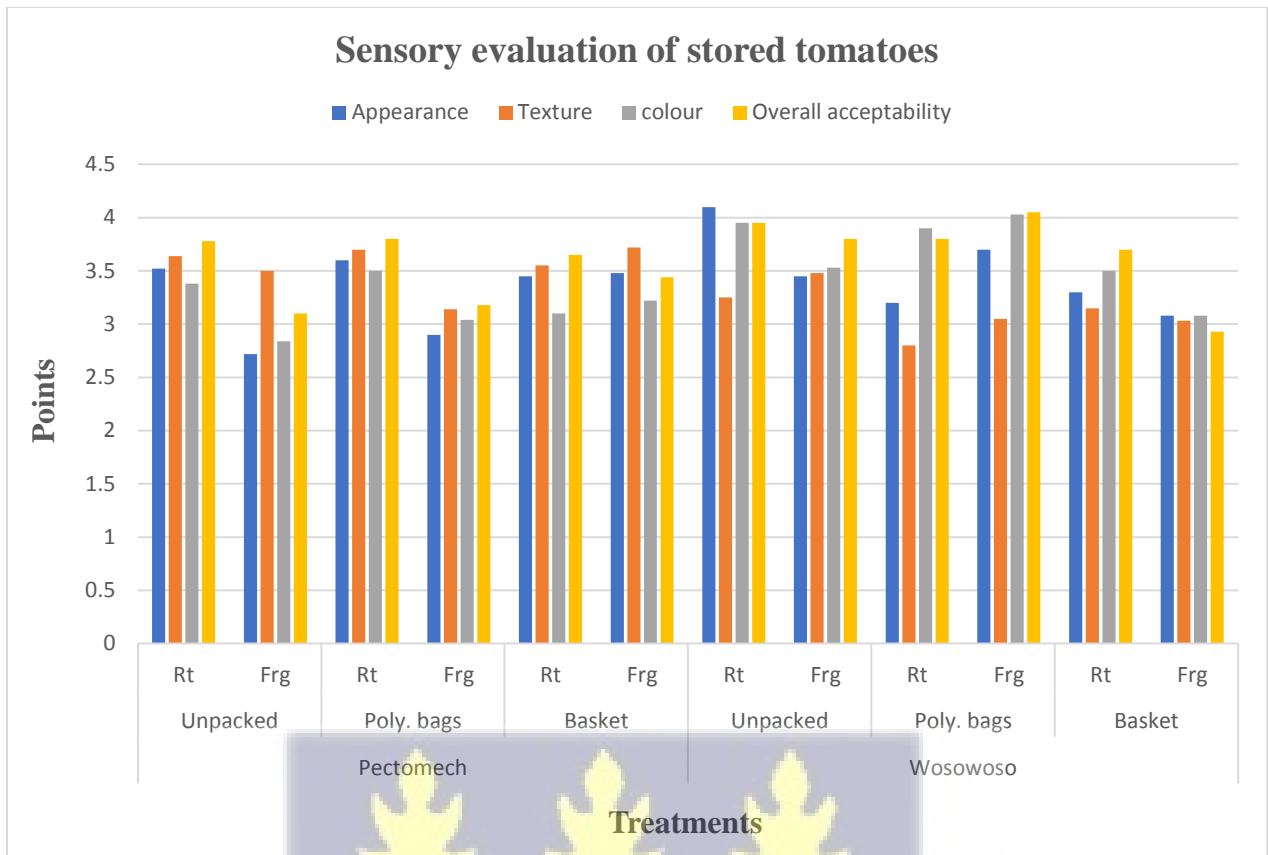
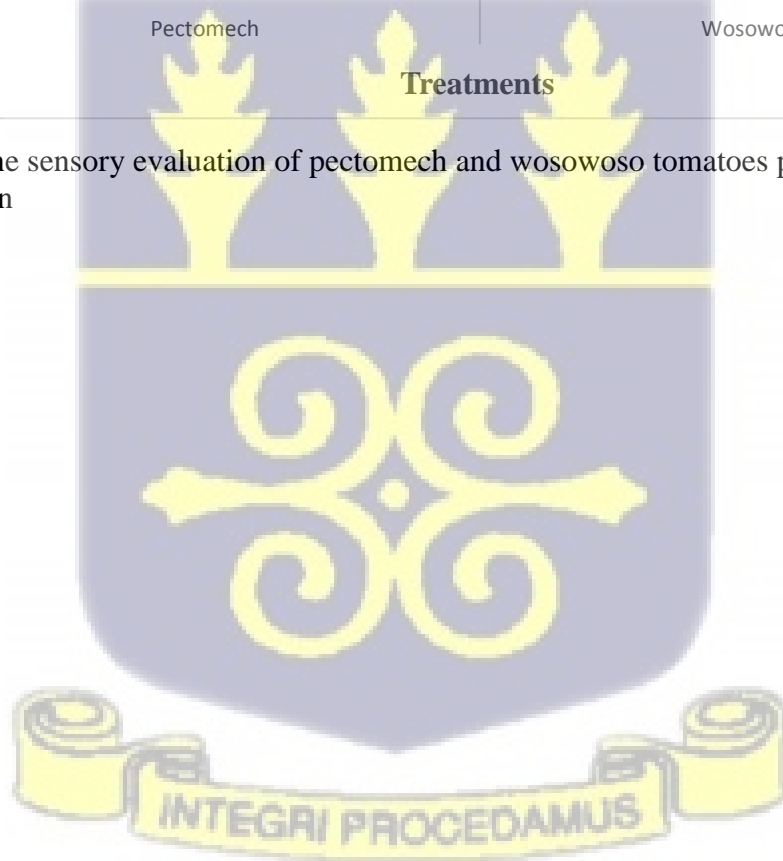


Figure 4.12. The sensory evaluation of pectomech and wosowoso tomatoes packed in room and refrigeration



CHAPTER FIVE

5.0 DISCUSSION

Experiment one

The present discussion is for the results from the 1st experiment in which different coatings and coating techniques were used to preserve tomatoes during storage at room and refrigeration temperatures. The cassava starch and citric acid and their combinations in different concentrations were coated by brushing and dipping on Pectomech tomatoes.

5.1 Effect of edible coatings on shelf-life of tomatoes stored at room temperature and at refrigeration.

The shelf life is the length of time a product may be stored without becoming unsuitable for use or consumption. It is the time in which a product will remain safe and retain desired sensory, chemical, physical and microbiological characteristics. The shelf life determination is important in assuring the safety and quality of the product. Some of the methods that can be used to prolong the shelf life of fruits is the use of improved postharvest treatment procedures, such as use of edible coatings and proper packaging materials. Some benefits of extending shelf life include keeping better quality of produce and less food loss and waste

In this study, for all method of applications used (Dipping and brushing), the shelf life of coated and stored pectomech tomatoes at refrigeration (4°C) was higher than that of room temperature (28°C).

The shorter shelf life obtained in control samples stored at room or refrigeration temperatures (28°C) or 4°C, may due to the higher respiration rate that occurred among the unwaxed fruits or it may also due to the different edible coating materials used which slowed down the rate of

respiration and reduced the rapid exchange of carbon dioxide and oxygen. The longer shelf life of samples dipped or brushed with edible coatings and stored at room temperature (28°C) or refrigeration temperature (4°C) was in line with the findings of Nurul (2012), who reported that cassava starch coating on fresh-cut pineapple delayed the change in colour, maintain quality of the pineapples and prolong the storage life. According to Gonzalez-Aguilar et al. (2010a), 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 the bee wax coating was very effective in improving the quality and extending the shelf life of sweet orange fruits at room temperature.

5.2. Effect of edible coatings on weight loss of pectomech tomatoes stored at room temperature and at refrigeration.

The fruits weight loss is the loss of water from fruits over a period after harvesting of the produce. Postharvest water loss in fruits and vegetable cause fruits deterioration where it results in a significant loss of fresh weight and economic loss when the fruits are sold by weight. 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.

During this study, the rate of weight loss occurred during storage of pectomech tomatoes was dependent on the type of edible coatings and storage place used to store them. For both method of application (Dipping and brushing) of edible coatings used, all treated samples stored at refrigeration (4°C) showed the low weight losses than samples stored at room temperature (28°C), where the first treatment which showed the very low weight loss than others was the samples stored in refrigeration and dipped in 1% of citric acid (1% CA, Dipping, Rft).

The high weight loss values obtained for pectomech tomatoes stored at room temperature (28°C), could be due to the higher temperature which can increase transpiration in stored tomatoes, and vice versa for tomatoes stored at refrigeration temperature (4°C). Similar inferences were made by (Perez et al., 2003) who reported that depending on the storage temperature, the weight loss of most fruits and vegetables is affected by water loss during storage. De Castro et al. (2006) also tested different storage temperatures and demonstrated that weight loss was proportional to the storage period and storage temperature. Transpiration of pectomech samples at room temperature (28°C) occurred at a higher level than samples stored at refrigeration temperature (4°C) as Wilson et al. (1999) indicated that transpiration is a major cause of deterioration because it results in direct weight loss due to loss of water. Different edible coatings can help prevent water loss by acting as water loss barriers, causing high relative humidity in the surrounding atmosphere of the fruits.

In this study the edible coatings used played a key role in reducing the weight loss. Low weight loss 0.67% of stored pectomech tomatoes was shown by samples treated with (2%CS, Dipping, Rft) on day 14 than 4.27% weight loss of non-coated and other coatings. This was in line with the work of Chumarrelli and Ferreira (2005) who observed the low weight loss in fruits coated with commercial carnauba-based (1.63%) than high weight loss (3.41%) of non-coated tomato fruits and coatings after 15 days. Jorge, et Al. (2011) also reported that the mineral oil coating reduced weight losses for up to 70% during storage.

5.3. Effect of edible coatings on the total soluble solid (TSS) of pectomech tomatoes stored at refrigeration and at room temperature

The total soluble solids are the amount of sugar and soluble minerals present in fruits and vegetables. During this study, the total soluble solids (TSS) was increased from day 0 to day 7 and started to decrease from 14th to day 21. This was similar to the work of Tigist, et al. (2013) who reported that the general trend observed during storage of different varieties of tomato fruits

was an initial increase in total soluble solids followed by a decrease from 16th day of storage period.

During storage period of this study, the TSS was increased at room and refrigeration temperature storage but at different level where the samples stored at room temperature (28°C) showed high increase in TSS values than samples stored at refrigeration temperature (4°C). The high Increase in TSS of tomato fruits stored at room temperature(28°C) could be due to high excessive water loss occurred there than at refrigeration storage. The ripening process of the fruits continue to happen even at refrigeration temperature storage but at the low level than room temperature storage. The increase of TSS may also due to the high ripening process of tomatoes stored at room temperature than refrigeration temperature during storage. This was in agreement with the work of Naik et al. (1993) who also reported that the total soluble solid increases during ripening as a result of degradation of polysaccharides to simple sugars which causes a rise in total soluble solids. The low increase in TSS of pectomech tomatoes stored at refrigeration (4°C) could due to the storage low temperature used (4°C) similar to the work of Dragan, et al. (2009) who stated that the total soluble solids increased during storage at 5°C. The reduction of TSS in this study may be caused by tomato fruits ripening process which was ended from day 14 of storage time.

5.4. Effect of edible coatings on firmness of pectomech tomatoes stored at refrigeration and at room temperature

The firmness is an important parameter used by the consumer to determine the quality of tomato fruits. Firmness is an indicator for determining the degree of maturation or ripening of tomatoes. This means that as the ripening increases the loss of firmness and less resistance on applied force increases (Jimenez et al., 2015). According to Ball (1997), the postharvest change in firmness can occur due to the loss of moisture through transpiration, as well as enzymatic changes. The edible coating can prevent softening of the fruit (Raghav, et al., 2016). The results

from table 4.2 of this study indicated that there was a significant decrease in the firmness of stored pectomech tomatoes. The treatment which showed a less decrease of firmness than control and other treated fruits was the samples stored in refrigeration and dipped in 3:1 ratio of cassava starch mixed with citric acid (3:1% CS+CA, dipping, Rft). This decrease in firmness with storage time was also observed by Bal (2013), who reported a loss of firmness in Plum fruits coated by Chitosan and stored at low temperature. Storage temperatures and time had significant effect on fruit firmness. During this study, fruits softened at both temperatures during the storage period. At the higher temperature, the decrease in firmness was more noticeable. This was similar to the work of Zhuang and Huang (2003); Basseto and Jacomino, Pinheiro (2005) who studied the effect of high temperature and extension of storage time on the softening of the fruits and the tomato samples lost firmness value through evaporation due to the temperature and extended storage. Ghaouth et al. (1992) also reported that fresh tomatoes coated with chitosan maintained more firmness than uncoated fruit after 28 days of storage at 20°C.

5.5. Effect of edible coatings on lycopene of pectomech tomatoes stored at refrigeration and at room temperature

Lycopene is an important quality index of tomatoes responsible for the formation of their red colour. Lycopene gives the characteristic of red colour and is the major carotenoid compound in tomato (Mwende, et al., 2018; Alda, et al., 2009). Due to its antioxidant property lycopene of tomato fruits plays a key role in dairy food diets. The results from this study indicated that, there was a significant increase in lycopene of coated tomatoes during storage.

The lycopene of fruits and vegetables increases with the increase of ripening, storage time and storage temperature, where the chlorophyll content decreases with rapid synthesis of the red pigment lycopene. During this study, storage temperatures and time had a significant effect on lycopene, where tomato lycopene content was increased more at room temperature (28°C) than

lycopene of samples stored in refrigeration temperature (4°C). Regarding all treatments used, samples dipped in cassava starch mixed with citric acid at 3:1 ratio and stored at room temperature (28°C) or simply, (3:1 CS+CA, dipp., Rt) was the first in showing high increase in lycopene value (33.62 - 86.34) than control and other treated samples during storage. This was in agreement with Javanmardi and Kubota (2006) who reported that the production of lycopene content is directly correlated with temperature range and rate of respiration during storage. According to Toor and Savage (2005) the lycopene level of tomatoes can be increased by storing them at 25°C. (Gonzalez, 2004; Henriquez et al., 2005) also reported that the low temperature delays lycopene pigment synthesis.

5.6. Effect of edible coatings on potential of Hydrogen (pH) of pectomech tomatoes stored at refrigeration and at room temperature

The pH is a measure of the concentration of hydrogen ions present in a food sample. The pH is used to express the concentration of free H_3O^+ in a sample and results from dissociation of the acids present. A lower pH value indicates a more acidic sample due to freer H_3O^+ , and a higher pH value indicates a more basic sample (The high pH results in low acidity of a product). The pH determination of a food produce, indicates the survival and development of microorganisms in a food produce. The pH of a product can be used to control microbial growth and product deterioration or decay. The low pH results in high acidity of a product where microbial attack is inhibited as according to Foolad, 2007 *Bacillus coagulans* activity in tomato was totally inhibited at pH values less than 4.1.

This study, revealed that the low increase of pH value (4.59 - 4.71) from day 0 to day 21 was recorded in fruits samples brushed with cassava starch at a concentration of 2% than other treatments used. The increase of pH recorded during this storage of pectomech tomatoes may be due to the storage time, high rate of metabolic activity and loss of citric acid inside the stored

tomatoes. This was in agreement with Tigist et al. (2013) who stated that the pH of tomato increases as the storage time increases. Anthon et al. (2011); Das et al. (2013) also stated that the pH increases as the acidity decreases due to changes to the loss of citric acid in tomatoes. Shahid et al. (2011) reported that the increase in pH in wax treated fruits might be due to the high rate of metabolic activities.

5.7. Effect of edible coatings on Vitamin c of pectomech tomatoes stored at refrigeration and at room temperature

Tomatoes are important sources of vitamin c. According to this study, it was indicated that the first treatment in terms of high increase in Vit.c than other treatments was the samples dipped in cassava starch and stored at room temperature (28°C) and at refrigeration temperature (4°C) or (3:1 CS+CA, dipping, Rt, Rft) with the Vitamin c values of (6.37 - 8.85) and (7.22 - 9.42) respectively, from day 7 to day 21. The increase of vitamin c found in this study, may due to the continued ripening process of stored tomatoes, which is in line with the work of Erip-Roberts, et al. (2002) who reported that the increase in ascorbic acid content in fruit is thought to be an indication that the fruit is still in the ripening stage. This increase in vitamin c contents of coated fruit, may also due to the type of edible coatings used which didn't prevent synthesis of ascorbic acid during ripening. Khalil et al. (2020) indicated that the tomato samples coated with glycerol, starch, and gelatin-based coatings had the high ascorbic acid concentrations during 14 days storage periods. Banu et al. (2020) also reported that tomatoes coated with red and brown algae had higher ascorbic acid contents compared with other tomatoes.

On the other side treatments which showed a decrease in Vitamin c were (0.5%CA, dipp, Rt) with Vitamin c value ranging from 9.9-6.54, (1%CA, dipp, Rft) with Vitamin c value ranging from 8.94-6.58; (2:1CS+CA, dipp. Rft) with Vitamin c value ranging from 8.2-5.67. The decrease of vitamin C may due to their senescent, long storage and physical damage as Lee, S.K. and Kader, A.A. 2000), indicated that some of the factors which can cause the loss of

Vitamin c include extended storage, physical damage and chilling injury. Erip-Roberts, et al. (2002) also reported that the decrease in ascorbic acid content in fruit is thought to be an indication that the fruit is in senescence process.

The treatments which showed initially increase followed by a decrease of Vitamin c were (0.5%CA dipp. Rft) with Vitamin c value ranging from 7.36 - 8.68 - 6.52; (1:0.5 CS+CA, dipp. Rft) with Vitamin c value ranging from 6.95 - 7.78 - 7.58; (1%CA brush, Rft) with Vitamin c value ranging from 5.68 - 9.62 - 8.65; (2:1CS+CA brush. Rft) with Vitamin c value ranging from 6.89 - 9.7 - 7.57. This may due to the factors such as ripening and extended storage, similar to the work of Helyes et al. (2006) who reported that Vitamin c content of tomatoes increased initially, but subsequently decreased with extended storage time.

5.8. Effect of edible coatings on titratable acidity (TA) of pectomech tomatoes stored at refrigeration and at room temperature

Total titratable acidity (TA) is a measure of the amount of acid or acids present in a food sample. The acidity of food products is a consequence of their formulation, including the amount and type of ingredients, additives, and preservatives used.

The results from table 4.3, indicated that, there was a significant decrease in TA value during storage of tomatoes. The first treatment which showed a low decrease in TA or high TA value during storage than other treatments was the sample which were dipped in citric acid 0.5% CA and stored at refrigeration(4°C) or simply (0.5% CA, dipping, Rft) with a TA value of 3.94 on day 21. The decrease in titratable acidity recorded in this study, was in line with the work of Bhatnagar et al. (2006) who stated that during storage of different tomato cultivars, the fruit itself might utilize the acid so that the acid in the fruits must decrease.

According to all determined quality parameters of pectomech tomatoes in experiments one, (3:1 CS+CA), which is the samples stored in cassava starch mixed with citric acid at 3:1 ratio

was the first treatment than others in showing good performance. This treatment was used to coat two varieties of tomatoes (Pectomech and wosowoso) in experiment two.

Experiment Two

The following discussion is for the results from experiment two in which coated samples comprising pectomech and wosowoso tomatoes varieties were packed in polyethylene and plastic bags and kept at room and refrigeration temperatures.

5.9. Effect of packaging materials on shelf life of pectomech and wosowoso varieties of tomatoes stored at refrigeration and at room temperature

The shelf life is the period (storage days) in which the quality of a produce can be maintained according to its storage conditions. It is the period of time from harvesting and extends up to the start of rotting of fruits (Mondal, 2000). It is used in commercial value chain to help producers and a distributors or sellers to determine the risks that can be happened (Radajewska and Borowiak, 2002). The significant increase in shelf life of packed and stored pectomech and wosowoso tomatoes was observed in this study.

The result from figure 4.5 shows that during storage, the shelf life of all samples of two varieties (pectomech and wosowoso), packed in polyethylene bags or baskets was higher than control (unpacked tomatoes) samples stored at room temperature (28°C) or refrigeration temperature (4°C). This was in line with the work of Srinivasa et al. (2006) who reported that the shelf life of tomato fruits can be delayed by an enclosure of tomato fruits in polyethylene or other forms of plastic packaging materials.

In all the two varieties, the shelf life of samples stored in refrigeration (4°C) was higher than that of samples stored in room temperature (28°C). This was in line with the work of Gonzalez-Aguilar et al. (2010) who reported that the use of edible coatings in conjunction with low-

temperature storage appears to be a promising approach in minimizing many postharvest problems and preserve the freshness of tomatoes. According to Dragan, Tomaž (2006), the storage life of tomatoes at 5⁰C was extended up to 28 days. The shelf life of pectomech samples was higher than that of wosowoso variety in all storages (28⁰C and 4⁰C), packed, and control samples.

5.10. Effect of packaging materials on weight loss of tomatoes varieties stored at refrigeration and at room temperature.

The weight loss of tomato fruits can be defined as the loss of water during their storage. The weight loss is one of important quality indices of tomatoes which varied according to the variety. The weight loss determination is used to know how the product is deteriorated and how it will affect traders and consumers. The significant increase in weight loss of packed and stored pectomech and wosowoso tomatoes was observed in this study.

The results from figure 4.6, indicated that the pectomech samples which were stored at refrigeration temperature (4⁰C) and packed in polyethylene bags showed the low weight loss percentage (50.95%) on day 28 than control and basket samples. Polyethylene packaging was better in storing pectomech tomatoes either in room or refrigeration storage than control and baskets packaging similar to the work of Muhammad Shahnawaz et al. (2012) who reported that tomatoes wrapped in polyethylene bags showed a minimum weight loss during 28 days of storage. The low weight loss obtained in this study, may due to the good packaging materials used as Coles et al. (2003) reported that good packaging preserve food through the prevention of product spoilage and wastage, and by protecting products until they have performed their function.

Polyethylene bag was also better than control and baskets packaging in terms of weight loss of pectomech or wosowoso samples which were packed in polyethylene bag. However, it was

indicated that the weight losses for wosowoso were higher than that of pectomech variety during storage at room (28°C) and refrigeration temperature (4°C).

Considering pectomech and wosowoso tomato varieties in terms of weight loss, pectomech showed the low weight loss (1.06%) on day 7 and 21.15% weight loss on day 21 at room and refrigeration temperature respectively than wosowoso variety. The high or low weight loss in wosowoso and pectomech obtained in this study was due to the type of variety which is in line with the work of Srivalli et al. (2016) who indicated that the variation of tomato weight loss depends on different varieties.

5.11 Effect of packaging materials on lycopene value of varieties of tomatoes stored at refrigeration and at room temperature

Lycopene is the main carotenoid found in tomatoes. Lycopene is responsible for the color change of tomatoes during ripening process. Lycopene is the major carotenoid compound of tomato, with bright red carotenoid pigment and phytochemicals found in tomato and other red fruit (Mwende, et al., 2018). Due to the strong color and non-toxicity of lycopene, it is a useful food colouring (Alda, et al., 2009).

The significant increase in lycopene of packed and stored pectomech and wosowoso tomatoes was observed in this study, where table 4.5, indicated that the pectomech or wosowoso samples which were stored at refrigeration temperature (4°C) and packed in baskets had a lycopene value of 11.55 and 16.43 on day 21 respectively. This result indicated that, the lycopene value of wosowoso packed in basket was higher than that of pectomech samples.

For the pectomech samples which were stored at room temperature (28°C), the samples packed in polyethylene bag showed the high increase in lycopene value from (5.43 - 31.77) on day 14 than control and basket samples while for the pectomech samples which were stored at refrigeration temperature (4°C), the samples packed in polyethylene bags also showed the high

increase in lycopene value from (4.37 - 26.30) on day 21 than control and basket samples. The polyethylene packaging was better than control and basket in terms of lycopene of stored pectomech tomatoes stored at both room temperature (28°C) and refrigeration temperature (4°C) this was in line with Coles et al. (2003) who reported that good packaging preserve food by protecting products until they have performed their function.

The lycopene at room temperature, was increased at the high level than that of refrigeration temperature for both stored pectomech and wosowoso varieties of tomato. The high increase of lycopene in this study, may due to the storage temperature (28°C) similar to the work of Toor, et al. (2005) who reported that the lycopene level of tomatoes can be increased by storing them at 25°C and Javanmardi and Kubota (2006) who reported that the formation of lycopene depends on the temperature range and rate of respiration during storage. According to Dumas et al. (2003), the optimum temperature range for lycopene synthesis is between 12 and 32°C.

5. 12. Effect of packaging materials on Vitamin c value of tomatoes varieties stored at refrigeration and at room temperature

Tomatoes are important sources of vitamin c. The result from figure 4.7 showed that the vitamin C value was significantly decreased with storage time for all stored coated and packed tomato samples, where the control pectomech or wosowoso samples which were stored in refrigeration temperature(4°C) had the Vit.c value ranging from 5.57 - 4.27 and 6.03 - 4 on day 21 respectively. The pectomech or wosowoso samples which were stored in refrigeration temperature (4°C) and packed in polyethylene bags had the Vit.c value ranging from 5.97 - 4.36 and 5.87 - 4.09 on day 21 respectively. The pectomech or wosowoso samples which were stored in refrigeration temperature (4°C) and packed in baskets had a Vit.c value ranging from 5.97 - 3.98 and 6.27 - 3.78 on day 21 respectively.

Considering all the two varieties used in this study, their Vit.c was decreased, and the Vit.c of pectomech was higher than that of wosowoso during their storage at room or refrigeration temperature. The decrease of Vitamin c results recorded in this study may be influenced by various packaging materials (Polyethylene and basket) used during storage, as Muhammad, et al. (2012), reported that the polyethylene bag was a better packaging material to retain good quality attributes in tomatoes during storage where tomatoes wrapped in polyethylene bags had better quality in terms of vitamin C content. The loss of vitamin C may also due to the storage time, where according to Adis, et al. (2001) the increase of storage period causes a decrease of vitamin C in fruits and vegetables. Zekrehiwot, et al. (2016) also reported a reduction in ascorbic acid of coated tomatoes during storage period.

5. 13. Effect of packaging materials on total soluble solid (TSS) value of varieties of tomatoes stored at refrigeration and at room temperature

The total soluble solid is the sugar content of a product. During this study, table 4.7 showed that, there was a significant increase in TSS value of packed and unpacked tomatoes. This was similar to the work of Dragan and Tomaž (2006) who demonstrated an increase of TSS (Total Soluble Solids) during 21 days of storage period. This was also in line with Muhammad, et Al. (2012) who reported that tomatoes packed in different wrapping materials showed an increase of TSS during storage.

The increase in TSS was higher in samples stored at room (28°C) than refrigeration temperature (4°C) for all the two varieties. This was similar to the work of Park, et al. (2004); Jeong, et al. (2005); Nei et al. (2005) who reported that the total soluble solid of tomatoes increases at different temperatures and packaging materials. According to Tigist, et al. (2013), The TSS of different variety of tomato fruits stored under ambient conditions was increased and the general trend observed during storage was an initial increase in total soluble solids followed by a decrease from 16th day of storage period.

5. 14. Effects of packaging material on potential Hydrogen value (pH) of coated tomato varieties stored at room temperature and at refrigeration temperature.

The pH of fruits and vegetables is the measure of the strength of the acids in them. The measurement of pH determines development of microorganisms in a food produce. The pH is used in food industry, where they use it to control microbial growth and product deterioration.

From the results the Pectomech samples stored at room temperature and packed in polyethylene bag or baskets showed the low level of pH (4.60) to the pH value of wosowoso (4.89) in polyethylene bags and (4.67) in baskets on day 7 of storage, while the wosowoso samples stored at refrigeration temperature (4°C) showed low level of pH 4.18 in polyethylene bags and 4.38 in baskets to the pectomech pH value (4.57 in polyethylene and 5.18 in baskets) on day 7. These results of low level in pH for both stored varieties of tomato were selected as the best ones in terms of pH due to the work of Foolad (2007) who reported that the lower fruit pH reduces the risk of pathogenic attack. The low pH values results obtained in pectomech or wosowoso varieties were included in the range of pH studied by Abouagye-Nuamah and Ackun (2018) who reported that the pH of tomato fruits from stored six varieties was in the range of (4.3 - 5.3).

5. 15. Effects of packaging material on titratable acidity (TA) of coated tomato varieties stored at room temperature and at refrigeration temperature.

Titrate acidity measurement determines the survival of microorganisms in a food produce that is why food processors use it to control microbial growth and deterioration of a products.

According to the result from table 4.8, the control and baskets pectomech samples stored in room showed high TA value than wosowoso, while control and baskets wosowoso samples stored in refrigeration, showed high TA than pectomech samples.

In polyethylene packaging, the high TA was recorded in wosowoso samples stored in room than pectomech samples, and high TA in pectomech samples stored in refrigeration than wosowoso samples. The results from this study, showed that there was a significant decrease in acidity during storage of non-packed or packed pectomech and wosowoso varieties, at 28 or 4°C respectively. The decrease in TA value may due to the storage time and temperature, similar with the work of Abebe, et Al. (2016) who reported that the titratable acidity (TA) decreased with storage time of tomato fruits. Dragan and Tomaž (2006) also showed a decrease of TA at different temperatures.

5.16. Sensory Evaluation

The sensory evaluation is sensory analysis which use human senses for the purpose of evaluating consumer products.

During sensory evaluation results, figure 4.8, showed that packaging materials had significant effect on appearance, texture, colour, and overall acceptability.

Considering all the sensory attributes in wosowoso variety, the panellist preferred coated tomatoes packed in polyethylene bags and stored at refrigeration 4°C than control and baskets samples, except in texture and appearance where the control samples stored at room temperature(28°C) were the most preferred, whereas in pectomech variety, in all sensory attributes examined the panellist preferred more tomatoes packed in polyethylene bags and stored at room temperature(28°C), and baskets samples at refrigeration temperature(4°C).

CHAPTER SIX

6. CONCLUSION AND RECOMMENDATIONS

The result from this study, indicated that, different edible coatings in treated samples increased shelf life of pectomech tomatoes than control (uncoated samples). The samples stored at refrigeration temperature (4°C) showed the high shelf life in all coated pectomech tomato samples than samples stored at room temperature. It is recommended to coat tomatoes before storing them because edible coating materials can slow down the rate of respiration and increase the shelf-life of tomato fruit. The use of right refrigeration temperature (4°C) storage is also recommended because it reduces respiration of produce. The percentage weight loss of pectomech tomatoes was increased with storage period. For all treatments, the tomatoes which were stored at room temperature 28°C showed the highest weight loss than those stored at refrigeration (4°C). The first treatment which showed the very low weight loss than other treatments was the samples stored at refrigeration temperature and dipped in 1% of citric acid (1% CA, Dipping, Rft). This treatment can be used to reduce weight loss in tomato storage. The total soluble solid was increased during storage, and the samples stored at room temperature (28°C) showed high TSS values than samples stored at refrigeration temperature. The treatments which showed high TSS value during storage was the samples stored at room temperature and dipped in 1% of citric acid (1% CA, dipping, Rt). The sugar content was increased after harvest and decreased at the end of storage period due to their uses in fruit respiration as an energy source. There was a decrease in firmness with time. The change in firmness can occur due to the loss of moisture through transpiration, as well as enzymatic changes. The (3:1% CS+CA, dipping, Rft) was able to prevent softening of the tomato fruits. Lycopene was increased with the storage time and temperature. The treatment (3:1 CS+CA, brushing, Rt) showed the positive effect of edible coating in allowing lycopene synthesis in

tomato fruits stored at room temperatures and refrigeration temperature than uncoated fruit during storage time by showing the highest lycopene value. The high temperature (28°C) increased the lycopene than low temperature (4°C). The pH was increased in this study, and (2% CS, brushing, Rft) treatment showed the low increase in pH corresponding to the high titratable acidity (TA) responsible to the reduction of microbial attack. The treatment (3:1 CS+CA, dipping, Rt, Rft) showed the high value of vitamin c on day 21 at room and refrigeration temperature storage than other treatments. The treatment (0.5% CA, dipping, Rft) showed the high TA value during storage. The best of the best treatments (3:1 CS+CA) in this study, was chosen to coat packed and stored two varieties of tomatoes (Pectomech and wosowoso) used in experiment two. It is recommended to all stakeholders to use (3:1 CS+CA) as edible coating when they are storing their tomatoes.

During storage, the packed samples in Polyethylene or baskets showed high shelf life in all the two varieties than control (unpacked tomatoes) samples at room temperature (28°C) or refrigeration temperature (4°C). Again, in all the two varieties, the shelf life of samples stored at refrigeration (4°C) was higher than that of samples stored at room temperature (28°C). The shelf life of pectomech samples was higher than that of wosowoso variety in all storage temperature (28°C and 4°C). It is recommended to use pectomech tomatoes if you need the variety which can live longer. The weight loss was varied according to the variety, and it was increased during storage of packed pectomech and wosowoso tomatoes. Polyethylene packaging was better or good packaging materials in reducing weight loss of stored pectomech or wosowoso tomatoes either at room or refrigeration storage than control and baskets packaging storage. The polyethylene packaging was better than control and basket in terms of lycopene of stored pectomech tomatoes stored at both room temperature (28°C) and refrigeration temperature (4°C). The lycopene in room temperature, was higher than that of refrigeration temperature for both stored pectomech and wosowoso varieties of tomato.

Tomatoes wrapped in polyethylene bags had high vitamin c content. The total soluble solid was (TSS) was higher in samples stored at room (28°C) than at refrigeration temperature (4°C) for all the two varieties. Polyethylene packaging was better in showing high TSS value for pectomech stored at room temperature than wosowoso, while polyethylene packaging was better in showing high TSS value for wosowoso stored in refrigeration than pectomech. In general, the Pectomech was better than wosowoso in showing the low level of pH corresponding to the high level of acidity responsible for microbial attack of the fruit in samples stored at room temperature, while wosowoso also showed a low level of pH than pectomech for the samples stored at refrigeration temperature (4°C). There was a significant decrease in acidity during storage of the two varieties (pectomech and wosowoso) packed in polyethylene bags or in baskets at 28 or 4°C respectively. The control and baskets pectomech samples stored at room temperature showed high TA value than wosowoso, while at refrigeration temperature (4°C) were the control and baskets wosowoso samples which showed high TA than pectomech samples. The polyethylene packaging showed high TA in wosowoso samples stored at room temperature (28°C) than pectomech samples, and at refrigeration temperature (4°C) high TA was observed in pectomech samples than wosowoso samples.

The sensory evaluation showed that packaging materials had significant effect on appearance, texture, colour, and overall acceptability. Considering all sensory attributes of pectomech variety stored at room temperature (28°C) or at refrigeration (4°C), polyethylene bags were preferred more than control and basket samples, while in wosowoso variety, the coated tomatoes packed in polyethylene bags and stored at refrigeration (4°C) were the most preferred than control and baskets samples, except in texture where the control were the most preferred.

In general, polyethylene packaging preserved the quality of two varieties of tomatoes (Pectomech and wosowoso) than control and basket packaging where the samples packed polyethylene bags were most preferred by consumers

It is recommended to coat tomatoes with right edible coating concentrations before storing them because edible coating materials can slow down the rate of respiration. The use of refrigeration storage for coated tomatoes and packed in polyethylene bags is also recommended. Farmers and traders should be encouraged to pack pectomech tomatoes in polyethylene bags when they are storing them at room temperature and in basket when they are going to use refrigeration storage.



CHAPTER SEVEN

7.1 REFERENCE

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