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ADDIS ABABA UNIVERSITY

COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES

CENTER FOR FOOD SCIENCE

The effect of composite edible film coating technology on the storage period and qualityof tomato

By

Ibrahim Abebe

Advisors

Dr. Paulos Getachew (Associate professor)

A Thesis Submitted to Center for Food Science , College of Natural and Computational sciences, Addis Ababa University; For Partial Fulfillment of Masters of Science Degree in Food Science and Nutrition

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
APHA	American public health Association
ATP	Adenosine triphosphate
CAS	Controlled Atmosphere Storage
CRD	Completely Randomized Design
CSA	Central Statistics Authority
EC	Electrical Conductivity
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
kPa	Kilopascal
LSD	Least Significant Difference
MAP	Modified Atmosphere Packaging
MARC	Melkasa Agricultural Research Center
MPN	Most Probable Number
pH	Potential hydrogen
PHM	Postharvest Management
RH	Relative Humidity
SD	Standard deviation
SPSS	Statistical Package for the Social Sciences
TA	Titratable Acidity
TCA	tricarboxylic acid
TSS	Total Soluble Solid
UAAIE	Upper Awash Agro-Industry Enterprise
USDA	United States Department of Agriculture
UV	Ultraviolet
WHO	World Health Organization
WL	Weight loss

.

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Abstract

Coatings were demonstrated to be possible for application due to their edible , non-reactive,and biodegradable nature. The aim of the study was to investigate the use of edible film coating materials on the extending the shelf life of tomato. Three different coating materials in combined with others and alone were used for the study. The tomatoes sample were subjected to seven experimental groups and coated with edible coating materials. The Physico- chemical analysis, proximate analysis, sensory analysis and the microbial load of the samples were evaluated at five days interval during the storage period. The maximum storage day was recorded 35 and 30 days in bees wax alone and bees wax with pectin (1:1). The weight loss percentages for chitosan with wax coated tomato (1:1), pectin with chitosan, pectin, pectin with wax (1:1) and wax coated samples were recorded as 25.55 %, 22.66 %, 17.81%, 14.04 % and 9.47 % respectively. The Total Soluble Solids (TSS) of tomatoes was increases from 4. 49 to 5.72 in controlled sample within 15 days, bees wax coated tomatoes were increased from 3.98- 5.03 in 35 days of storage period. The acidity of stored tomatoes were decreased from 6.67 to 4.73 in control sample within 15 days, 5.37 to 4.17 in bees wax coated tomato within 30 days, 7.06 to 3.87 in pectin coated tomato within 30 days, chitosan coated decreased from 7.06 to 3.87 within 25 days of storage period, from 7.23 to 4.59 in 1:1 pectin and chitosan coated materials within 30 days of storage period, 5.93 to 3.57 in 1:1 pectin and wax coated tomato within 35 days of storage. The lycopene content of tomatoes were showed that an increment from 14.08 to 18.30, 3.5 to 16.66, 15.77 to 17.53, 7.75 to 11.10, 17.47 to 24.41, 14.83 to 20.58, 11.69 to 14.9 respectively in control, bees wax, chitosan, pectin, pectin with chitosan, pectin with bees wax, chitosan with beeswax. The microbial load (plate count) of the stored tomato at different coating materials such as pectin, chitosan, bees wax and combined with each other were recorded nil or no growth up to 15 days. In control sample 10cfu/ml was recorded in the 15 days of storage. Yeast and mold count growth also nil within 15 days of storage period, while in control (uncoated tomato) 11cfu/ml at dilution factor $10^{-3.}$ The control treatment has relatively lower scores across all sensory attributes. The values for color (6.18), firmness (5.00), texture (5.09), odor (5.55), appearance (5.45), and overall acceptance (5.45) are among the lowest in comparison to other treatments. The findings showed that all prepared coatings could maintain qualitative features and extend the shelf life of tomatoes. The coatings made from citrus fruit (pectin), shrimp shell (chitosan), and beeswax (bee product) in equal proportions were the best combination of all coatings because they retained maximum quality attributes by inhibiting respiration and minimizing starch conversion into sugar. Therefore, coatings materials plays significant role on the extending shelf life of tomato for several storage days.

Keywords: Tomato, coating materials, Physicochemical Properties, Proximate Analysis and microbial analysis.

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1. INTRODUCTION

1.1 Background

Tomato (*Lycopersicon esculentum Mill.)* belonging to the family *Solanaceae* is a major horticultural crop. The World's production of fresh tomatoes in 2009 was about 141 million tons planted on 4.5 million hectares in 144 countries (FAOSTAT, 2013). It is one of the most widely consumed, and the second most important vegetable crops, next to potato worldwide (Pantheen and Chen, 2010). Tomato is among the most important vegetable crops in Ethiopia and both fresh and processed tomato varieties are popular and widely produced (Menberu *et al*., 2012). In recent years, commercial tomato production in Ethiopia has significantly expanded since national agricultural strategies began favouring high value cash crops. In 2014, tomato produced in Ethiopia was close to 55, 000 tons which was expected to increase by 2016 (FAOSTAT, 2016).

Tomatoes are a popular vegetable crop that can supply a considerable amount of the total antioxidants in the diet (Martinez-Valverde *et al*., 2002). It is regarded as one of the most health-promoting vegetables due to the antioxidant effects of certain components. Antioxidants include vitamins C and E, lycopene, ß-carotene, flavonoids, and other phenolic compounds (Dumas *et al*., 2003). It is generally recognized that phenolic chemicals improve fruit quality and nutritional value by affecting color, taste, aroma, and flavor, as well as giving health benefits (Hagen *et al*., 2007). Despite the importance of this crop, the production and productivity are constrained by different biophysical and socio-economic reasons, such as lack of adapted and improved tomato technologies, inadequate knowledge of production and management (processing) systems, poor extension services, poor marketing system and proper utilization of the crop are a few to mention. Tomato is one of the most perishable fruits and it changes continuously after harvesting. Depending on the humidity and temperature it ripens very soon, ultimately resulting in poor quality as the fruit become soft and unacceptable.It is a relatively short duration crop; because of its high moisture contents are inherently more susceptible to deterioration especially under higher temperature conditions (Ofosu-Anim *et al*., 2007).

Tomatoes are climacteric fruits that experience a respiratory peak during the ripening process. Metabolic activity in fresh tomato crop continues after harvest, and deterioration rates rise due to ripening, senescence, and unfavorable environmental conditions. Several physiological processes, including as respiration, transpiration, and ethylene production, contribute significantly to the degeneration of horticultural crops (Yahia, 2019). Fresh fruits and vegetables deteriorate mostly due to continuous metabolic processes, water loss, physiological problems, mechanical damage, and pathological collapse (Wills *et al*., 2007).

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Water loss during storage affects the quality of most fruits and vegetables, which is determined by the storage temperature and relative humidity (Perez *et al*., 2003). In tropical countries, the loss between harvesting, transportation, and consumption might range from 20 to 50% (Pila *et al*., 2010). Postharvest losses are the measured quantitative and qualitative food losses in the postharvest system (Aramyan and van Gogh, 2014; FAO, 2013). Losses in fresh horticultural produce are directly linked to quality decline. Quality loss occurs as a result of inappropriate handling and transportation during the sale of produce. Postharvest losses, which range between 24 and 40% in impoverished countries and 2 to 20% in industrialized ones, are a significant source of waste. High levels of waste raise the price of fresh produce, and farmers are increasingly suffering destitution (Rosa 2006).

The perishability of tomatoes requires the development of technologies that will reduce postharvest deterioration and extend its shelf life (Gonzalez- Aguilar *et al*., 2009). Tomato fruit kept within sealed packages resulted in an atmosphere with high CO_2 and low O_2 content. These conditions retained flesh firmness, low acidity and soluble solids concentration and delayed fruit lycopene (Sabir and Agar, 2011). Many storage techniques have been developed to extend the proper marketing distances and holding periods for fresh horticultural crops after harvest. Among those maintaining the produce at low temperature and high relative humidity, under controlled atmosphere storage, and/or modified atmosphere packaging.

The use of edible film coating is growing inimportance because it is convenient in the many different conditions throughout the chain of handling from producer to consumer. During storage, fruit and vegetables deteriorate through the action of spoilage microorganisms. Postharvest illnesses contribute significantly to postharvest loss due to a lack of adequate postharvest storage facilities, particularly in underdeveloped countries (Singh et al., 2017). Microbial degradation is mostly caused by fungi, yeast, molds, and bacteria (Yahaya and Mardiyya, 2019). Postharvest physiology and technology have been critical elements in maintaining and prolonging the storage life of perishable commodities (Pedreschi, 2017). The quality of fresh tomatoes is mainlydetermined by appearance (color, visual aspects), firmness, flavour and nutritive value (Giovannoni, 2001). Therefore, developing a technology that extends the tomato's postharvest life is necessary to reach consumers with the minimally altered nutritional and sensory qualities.

To minimize the storage problems nowadays, simple and effective technology required to improve the postharvest losses of tomato produces. Among the technologies the edible film coating materials such as pectin, chitosan, beeswax and their combinations are important to

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reduce the postharvest losses. The edible film coating of tomato is the best option to extend the shelf life of tomato to reasonable days by creating modified packaging environments on the harvested tomatoes. Edible coatings are thin layer of material that provides a barrier to moisture, oxygen and solute movement for the food. It can be a complete food coating or can be disposed of as a continuous layer between food components (Gol *et al*., 2013). The use of edible coating has also received more attention in recent years, due to the growing interest in reducing environmental pollution caused by plastics, the need to extend the shelf life of foods, and the increasing demand for healthier and ecological foods (Espino-Díaz *et al*., 2010).

Therefore, this work aims to determine the individual edible coating materials and combined effects extended the storage days of tomato fruits.

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1.2 Statement of the problem

Postharvest losses are a major problem that threatens food security, economic growth, and sustainable farming in Sub-Saharan Africa, especially in Ethiopia. Tomatoes (Solanum lycopersicum) are among the most affected perishable crops due to their climacteric nature, high respiration rate, and soft texture. Studies show that postharvest losses for tomatoes in this region range from 20% to 50%. This is mainly caused by poor harvesting methods, inefficient transportation, and insufficient storage facilities (FAOSTAT, 2014; Affognon et al., 2015).

In Ethiopia, the lack of suitable storage technology worsens the situation, leading to significant losses in both quantity and quality of fruits and vegetables. These losses are estimated to be between 15% and 45%, depending on the crop and area (Neglo et al., 2021; Assan, 2023; Sousa et al., 2024). The decline in nutritional quality during storage, especially in vitamin C, lycopene, and other antioxidants, is a major concern. This decline affects the intake of essential nutrients for consumers (Kader, 2008; Rickman et al., 2007). Tomatoes are a vital source of micronutrients like vitamin C, potassium, and bioactive compounds such as lycopene. After harvest, they experience rapid physiological and biochemical changes. These changes include increased respiration, ethylene production, and oxidative stress, which result in softening, spoilage, and nutrient loss (Ali et al., 2011). Unfortunately, many smallholder farmers in Ethiopia cannot afford cold storage or controlled atmosphere systems to slow down spoilage. Consequently, they must sell their produce at low prices during peak harvest times, which causes financial losses and keeps them trapped in poverty and food insecurity (Adepoju, 2014; Mukherji et al., 2023).

The lack of affordable and effective postharvest technologies impacts everyone in the supply chain. Farmers receive less compensation for their work, while consumers pay higher prices for lower-quality goods due to postharvest losses. Additionally, the high perishability of tomatoes contributes to nutrient deficiencies in diets that already lack fresh produce (Rai et al., 2012). This makes reducing postharvest loss crucial not just for food quantity, but also for food quality and nutrition. One promising low-cost solution to reduce postharvest losses is the use of edible coatings. These coatings create a semi-permeable barrier to moisture, gases, and solutes. Edible films made from beeswax, pectin, and chitosan can change the internal environment of fruits by slowing down respiration, ethylene production, and microbial growth, thus extending shelf life and maintaining nutritional quality (Gol et al., 2013; Shahbazi, 2017).

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Therefore, improving postharvest processes through innovative, cost-effective technologies like edible film coatings is essential. It can extend the shelf life of tomatoes, improve nutritional quality, stabilize market prices, and support sustainable food systems in Ethiopia. This study aims to assess the combined effects of beeswax, pectin, and chitosan-based edible coatings on the postharvest shelf life and quality of tomatoes when stored at room temperature.

1.3 Research Questions

The key research questions of the study sought to answer will be

- ✓ To what extent does the edible film coating extend the shelf life of tomato?
- ✓ To what extent the physicochemical properties of tomato kept through edible film coating?

1.4 Hypothesis

- ✓ **Null hypothesis (Ho):** There is no difference between edible film coated and uncoated tomato in extending the shelf life of tomato.
- ✓ **Alternate hypothesis (Ha):** There is a significance difference between edible film coated and uncoated tomato in extending the shelf life of tomato.

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1.5 Significant of the study

Postharvest losses of fruits and vegetables remain a great barrier to achieving food and nutritional security, especially in developing countries such as Ethiopia. Tomatoes, among all fruits, are very prone to spoilage due to their large water content, climacteric, and sensitivity to microbial degradation. It leads to rapid quality reduction, limiting marketability and consumer availability of safe and healthy fruits (Affognon et al., 2015; FAO, 2023).

Using edible film coatings represents one of the most effective yet low-tech strategies for reducing postharvest losses. These coatings function as semi-permeable membranes, altering the internal environment of fruits and vegetables. This helps slow down the rate of respiration, moisture evaporation, microbial growth, and oxidative damage (Ozturk & Karaman, 2023). As a result, they help preserve the physical qualities (such as firmness, weight, and color) and nutritional content (like vitamin C and lycopene) of the stored produce (Riaz et al., 2022).

This research is important because it explores the use of three biodegradable and food-safe coatings beeswax, pectin, and chitosan that are known for extending shelf life and maintaining quality without relying on artificial preservatives. These natural coatings are particularly beneficial for smallholder farmers in Ethiopia, many of whom lack access to expensive storage methods like refrigeration or controlled-atmosphere systems (Nkuiya et al., 2022; Mukherji et al., 2023).

By extending the shelf life of tomatoes using these coatings and properly labeling the coated products, the study contributes to market supply stability, minimizes price fluctuations caused by seasonal changes, and ensures the availability of high-quality produce for both domestic and international markets. This also supports broader goals such as enhancing the sustainability of the food system, boosting farmer livelihoods, and advancing national objectives related to food security and economic development (FAO, 2023; Lalnunthari et al., 2023).

Therefore, outcomes of this study are expected to deliver a feasible and scalable intervention to reduce postharvest losses, enhance food quality, maximize the economic benefit to producers, and improve food system resilience in Ethiopia and similar agro-ecological conditions.

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1.6 Scope of the Study

This study is intended to determine the effectiveness of edible film coatings, particularly beeswax, pectin, and chitosan, in extending the postharvest storage period and quality of tomatoes (Solanum lycopersicum) Galilea hybrid under ambient storage. Its goal is to analyze the impact of these coatings on key physicochemical properties ,nutritional qualities, microbial analysis and sensory attributes. The research is limited to room temperature (non-chilled) conditions, which reflect the conditions of storage by smallholder farmers and local market actors in Ethiopia.

The study offers cost-effective, accessible, and environmentally friendly postharvest management practices with practical applications that are especially applicable in developing countries where there are inadequate or no cold chain facilities (Lalnunthari et al., 2023; FAO, 2023). The edible coatings selected herein are environmentally friendly, non-toxic, and studied elsewhere in the past concerning their effectiveness, which is a positive indicator of their ability to upscale in Ethiopian horticultural systems.

Besides, the study seeks to contribute to food loss reduction, improved food quality, and farmer income in accordance with sustainable agriculture and food system resilience (Nkuiya et al., 2022; Mukherji et al., 2023).

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1.7 Objectives

1.7.1 General objective

To extend the shelf life of tomato using combined treatment effect of edible film coating materials (beeswax, pectin, chitosan).

1.7.2 Specific objectives

- To characterize physicochemical properties of edible film coated tomatoes
- To evaluate the microbial quality of edible film-coated tomatoes
- To determine the shelf life of edible film-coated tomatoes
- To evaluate the organoleptic (sensory) quality of edible film-coated tomatoes

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2. LITERATURE REVIEW

2.1 Tomato production

2.1.1 World tomato production

Tomato (*lycopersicum esculentun*) is one of the most widely grown vegetables in the world (Srinivasan, 2010). It is estimated to be grown on more than 5 million hectares with aproduction of nearly 129 million tonnes. China tops the chart of tomato growers worldwide (Tabele1). Egypt, Nigeria, Tunisia and Morocco are the leading producers of tomato in Africa (FAOSTAT, 2008).

Table1. World's leading producers of tomato

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

Source: FAOSTAT. 2008, MT- Million tons

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2.1.2 **Tomato production in Ethiopia**

Tomato (*lycopersicum esculentun*) is a widely grown vegetable crop in Ethiopia. It is consumed in every household in different modes and it is also important co-staple food. It also represents an essential part of human diet. It is a good nutritional resource rich in vitamin C and antioxidant mainly lycopene, carotenes, organic acids and phenolics (Giovanelli and Paradiso, 2002). Organic acids which influence its shelf-life and organoleptic properties such as color brightness and texture contribute to acid-base balance for the consumer (Adedeji *et al*., 2006).

Tomato is a crop of high economic importance in many countries as it is a relatively short duration crop ,because of its high moisture contents are inherently more susceptible to deterioration especially under higher temperature conditions (Ofosu-Anim *et al*., 2007). Tomato is one of the most important vegetable crops in Ethiopia grown for fresh market and processing. It is the third important vegetable crop after red pepper and Ethiopian cabbage with acreage and production share of 4.53% and 10.82%, respectively (CSA, 2012).

Tomatoes are one of the main vegetable crops grown in Ethiopia. However, due to their highly perishable nature, they have a short shelf life. This results in an oversupply during the brief harvesting period and a shortage during the off-season, making them both scarce and costly. The lack of proper processing and preservation methods leads to significant revenue loss for farmers. In contrast, the United States, which ranks as the second-largest tomato producer after China, processed 89% of its tomato harvest in 2008, generating over $2 billion in farm income (Adegbola et al., 2012).

Ethiopia possesses a comparative advantage in various horticultural products because of its favorable climate, geographic closeness to European and Middle Eastern markets, and affordable labor. Despite these advantages, the countries horticultural crop production lags behind that of food grains. On average, public and private commercial farms in Ethiopia produce more than 2,399,566 tons of vegetables and fruits annually, which accounts for less than 2% of the nation’s total crop output. Data from the Central Statistics Authority indicates that in 2011, the total land area dedicated to fruit and vegetable cultivation was approximately 12,576 hectares.

Agriculture plays a central role in Ethiopia’s economy, contributing around 50% of the GDP, 90% of export earnings, and providing employment for 85% of the population. Globally,

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Ethiopia ranks third and first in Sub-Saharan Africa in terms of the proportion of its GDP derived from agriculture. Coffee is the leading export, accounting for 53% of export revenue, followed by t'chat. Other key exports include oilseeds, horticultural produce, livestock, and livestock products. Ethiopia also exports some processed fruits and vegetables, mainly to countries like Yemen, Saudi Arabia, and others in the Middle East. The leading processed agricultural exports are orange products (like canned or bottled juice) and tomato-based items (such as ketchup, tomato paste, and concentrates). Of Ethiopia's total land area of 111.5 million hectares, nearly two-thirds are suitable for agriculture. Effectively harnessing this land could significantly improve the livelihoods of the country's many smallholder farmers and pastoralists. However, only about 33% of this suitable land is currently in use. Smallholder farmers cultivate approximately 96.8% of the agricultural land and are responsible for producing 97.6% of the nation's agricultural output. In 2005, vegetables made up 2.7% of the total crop area (Jema, 2008).

2.1.3 **Nutritional composition of tomato**

The composition of tomato fruit covered by 96% of water. Sugars also an important component of tomato fruit as they determine sweetness and influence the overall tomato flavour. It has been documented that aroma is perceived with greater intensity when the level of reducing sugar is raised within a given range of acids (Baldwin *et al*., 1998). Sugars in tomato fruit are mostly comprised of glucose and fructose with trace amounts of sucrose. Increase in sugars renders the fruit much sweeter and more acceptable (Wills *et al*., 2007). Decrease in starch content accompanied by an increase in soluble solids and a total sugar is typical of postharvest change in climacteric fruit (Pinto *et al*., 2004). It is well known that sugars and simple acids are the respiration substrates. The longer the time of fruit respiration, the higher the rate of sugars and acids consumption (Atta-Aly, 1995). The total sugar content of ripe tomato is between 1.7 and 4.7% (Yilmaz, 2001).

Nutritionally, tomato is a rich source of vitamin B and phytonutrients, the most abundant in tomatoes are the carotenoids, lycopene being the most prominent, followed by beta-carotene and gamma-carotene, as well as several minor carotenoids (Beecher, 1998). Tomatos also provide antioxidants such as vitamin A, C and E that are important in neutralizing free radicals(oxidants) known to cause cataracts, hypertension, stroke and diabetes (Wargovich, 2000). Free radicals according to Filippone (2006), can potentially lead to cancer, heart disease and premature aging.Metabolic activity in fresh tomato produce continues even after harvest and the deterioration rate increases due to ripening, senescence and unfavorable environmental factors.

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Hence, preserving these types of foods in their fresh form demands that the chemical, bio-chemical and physiological changes are restricted to a minimum by close control of space temperature and humidity (Chandra *et al.* 1999).

Table 2.Nutritional composition of tomato

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

Source: USDA National Nutrient Database (2010)

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2.1.4 **Postharvest Losses of Tomatoes**

Postharvest losses tomatoes are a matter of concern for all those countries whose economy is based on agriculture. As this happens in almost every developing country that tomatoes are extremely perishable product that requires to be dealt with much care to reduce losses. Because of its high moisture content horticultural crops are inherently more susceptible to deterioration especially under higher temperature conditions. They are biologically active and carry out transpiration, respiration, ripening and other biochemical activities, which result in quality deterioration. The postharvest losses of fresh fruits and vegetables including tomatoes are estimated to be 5 to 25% in developed and 20 to 50% in developing countries (Kedar *et al* 2004).

Postharvest loss occurs when the fresh fruits and vegetables arrive in the market at its peak season due to its abundant availability the prices of all the products come down to such a level that the farmers instead of profit lose money. In such cases the need for proper storage and product preparation is very much needed. In developing the production may not be linked with the market that how much of such fruits are vegetable will be needed to properly process and utilized in fresh form. In such cases if the production is more there is no facility for its proper storage transportation packaging and handling the surplus product, so automatically going to be wasted. These have been highlighted as one of the determinants of the food problems in most developing countries (Babalola et *al.*, 2010). Evidence suggests that these losses tend to be the highest in those countries where the need for food is greater, some authorities put postharvest losses of sweet potatoes, tomatoes, bananas and citrus fruit sometimes as high as fifty percent (FAO, 2002).

Losses of tomato produces are caused by a wide variety of factors, ranging from growing conditions to handling at retail level. Not only are losses clearly a waste of food, but they also represent a similar waste of human effort, farm inputs, livelihoods, investments and scarce resources such as water. Postharvest losses for horticultural produce are, however, difficult to measure. In some cases everything harvested by a farmer may end up being sold to consumers. In others, losses or waste may be considerable (Mrema&Rolle, 2002). Post-harvest loss occurs between the completion of harvest and moment of human consumption. It is thus loss, which happens after separation of the product from the medium and site of immediate growth or production of the product (Cornelius &Obeng-Ofori, 2008). The quality and nutritional value of fresh tomato, is affected by postharvest handling and storage condition (Sablani *et al.*, 2006).

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The high perishability nature of tomato makes their handling, transportation and marketing a special problem particularly in the tropics. In developing countries, storage, packaging, transport, handling and preservation techniques are practically non-existent with perishable crops and so, this allows for considerable losses of produce. Thusas more fresh tomato fruits are needed to supply the growing population in developing countries, as more produce is transported to nonproducing areas and as more commodities are stored longer to obtain a year round supply, postharvest loss prevention technology measures become paramount (Oyekanmi, 2007).

Postharvest weight change in tomato is usually due to loss of water through transpiration. This loss of water can lead to wilting and shriveling, which both reduce market value and consumer acceptability (Ball, 1997). A number of chemical and physical processes take place in tomato during storage. The quality of most fruits and vegetables is affected by water loss during storage, which depends on the temperature and relative humidity conditions of storage (Perez et al., 2003). Consumers judge the quality of fresh tomatoes by their firmness, color and taste, which are related to ripeness and shelf life. Major losses in the quality and quantity of fresh vegetable and fruit products occur between harvest and consumption (Brooks et al., 2008).These are critically dependent upon different factors such as pre and postharvest, environment, desiccation, physiological process of maturation and senescence and the onset and rate of microbial growth. Temperature plays an important and key role on the shelf-life of tomato. Low temperature storage has been considered the most efficient method to maintain the quality of tomato due to its effects on reducing respiration rate, transpiration, ethylene production, ripening, and senescence and rot development. The effect of storage temperature on physiochemical quality and quantity changes in tomatoes varies with cultivars. The perishability of tomatoes requires the development of technologies that will reduce the postharvest deterioration and extend its shelf life (Gonzalez- Aguilar et al., 2009).

2.1.5 **Causes of postharvest losses in tomato storage**

There are several factors that cause postharvest loss of fruit and vegetable, starting from the pre harvesting stages up to end consumption. This aggravates the perishability of crops and the economic crisis of producers. From the possible loss factor, storage system covers the lion share of tomato loss. Storage can accelerate the losses due to respiratory metabolism of produces and environmental factors.

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I Respiration

Respiration is one of the cornerstones of plant life due to its crucial roles in carbon and energy metabolism. In all cells the respiratory pathways play a role in a wide range of physiological functions including ATP formation, the provision of carbon skeletons for biosynthesis, photorespiration, the regulation of cellular redox and potential roles in adaptive response to abiotic stress by minimizing the production of reactive oxygen species (ROS). Tomatoes are climacteric and show a pronounced increase in respiration during ripening. The intensity and duration of the climacteric varies among cultivars (Wills *et al.* 2007).

Respiration also varies with temperature and atmospheric composition. Respiratory metabolism in plants is comprised of a combination of different metabolic pathways. Glycolysis which is, at least partially, present in cytosol and plastids, the mitochondrialtricarboxylic acid (TCA) cycle which is present in the matrix of mitochondria and oxidative phosphorylation which occurs in the inner mitochondrial membrane represent the major components of aerobic respiration. In addition, substrates for the TCA cycle reactions or electrons for the mitochondrial electron transport chain can be supplied by various other pathways. Despite the fact that nearly all enzymes and proteins that participate in all these pathways have long been known and a large proportion of plant respiratory components share commonalities to those of better characterized organisms, the regulation and control of plant respiration as a whole is much less well understood (Fernie *et al*., 2004; Bunik&Fernie, 2009).

II Temperature

Temperature is the most important influencing factor on quality of tomatoes, including appearance, texture, composition and eating quality (Nunes, 2008). Low temperature not only reduces the rate of enzymatic reactions but also controls the growth of many decay-causing bacteria and fungi. Good temperature management is crucial in delaying produce deterioration and optimum quality can only be attained when the produce temperature is reduced to optimum temperature as soon as possible. However, delay in cooling and poor temperature management is difficult during handling, transport and storage, thus leading to loss of quality and reduction of maximum potential shelf life of fresh fruit and vegetables.

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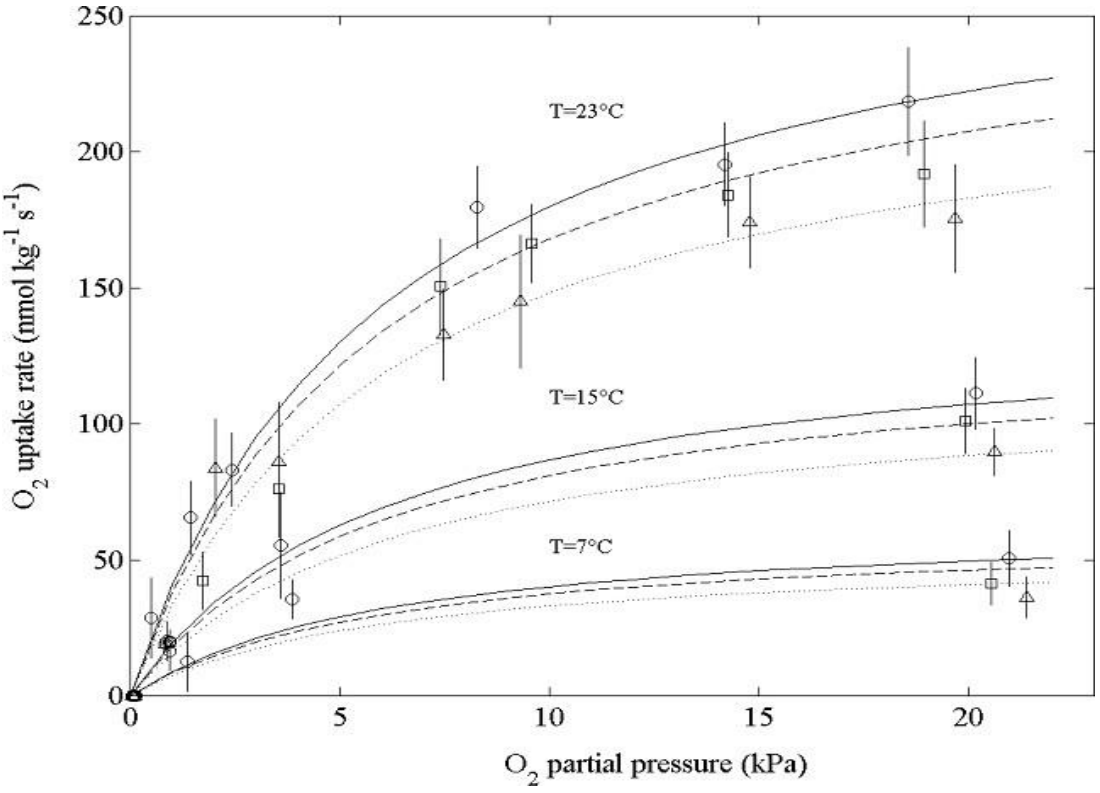

Figure1. Effect of temperature in the respiration of pear, by affecting oxygen uptake and carbon dioxide production. In each temperature three curves shows 0, 5, 10, 15, and 20kPa CO2 for upper, middle and lower line respectively (Lammertyn *et al*., 2001).

III Relative humidity

RH is another important factor that needs to be controlled during storage of tomato. It is particularly important in minimizing the difference in water vapor pressure between produce and the environment. The humidity of produce surrounding its environment should be maintained at a level that minimizes the water pressure deficit (Nunes, 2008). RH is too low, the transpiration will be enhanced, resulting in moisture loss, which is associated with produce softening, discoloration, loss of turgidity, wilting and shriveling and dryness. Moreover, the increase in moisture has been reported to accelerate fruit ripening (Nirupama *etal*., 2010). However, it is needed to note that high RH may also contribute to microbial growth. Optimum temperature and RH condition for a specific produce must be established to ensure quality preservation and maximum shelf life.

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IV Atmospheric composition

Modification of the atmospheric gas composition surrounding tomato storage has been used successfully in extending shelf life and maintaining quality (Nunes, 2008; Vigneault *et al*., 2012). Normally, atmosphere modification refers to controlled atmosphere (CA) and modified atmosphere packaging (MAP), both of which involve the reduction of O_2 and the elevation of CO_2. MAP of fresh produce relies on modification of the atmosphere inside the package, achieved by the natural interplay between two processes, the respiration of the product and the transfer of gases through the packaging that leads to an atmosphere richer in CO_2 and poorer in O_2. This atmosphere can potentially reduce respirationrate, ethylene sensitivity and production, decay and physiological changes, namely, oxidation (Gorris& Tauscher, 1999). The changes in atmosphere concentration have effects on produce both in terms of physiology and microbiology. Low O_2 concentration can reduce respiration rate of produce by modifying or retarding the normal biochemical reaction, thereby retaining their color, taste and texture. Also, low O_2 atmospheres effectively reduce the proliferation of aerobic bacteria, especially gram-positive microerophiles such as *Lactobacillus*. On the other hand, high O_2 atmosphere can also cause O_2 toxicity to microorganisms, bacteria, yeasts and moulds (Kader and Ben- Yehoshua, 2000). An increase in CO_2 concentration in the storage atmosphere can reduce respiration rate as well by inhibiting some enzymatic activities and decreasing the synthetic reaction of ripening. In addition, high CO_2 atmospheres inhibit most aerobic microorganisms, especially gram-negative bacteria and moulds (Al-Ati& Hotchkiss, 2002).

The gas concentrations used in atmosphere modification depend on the species, origin, its maturity or ripeness stage, the storage duration, temperature, Relative humidity and the tolerance of the tomato to high levels of CO_2 or low level of O_2.Thus, the control of gas compositions is very important. For instance, if the O_2 concentration is too low, anaerobic respiration may occur, adverselyaffecting the quality of fruit and vegetables (Sandhya, 2010). Excess CO_2 causes injuries such as softening, off-flavors and discoloration (Nakamura *et al*., 2004)**.**

V Ethylene production

Ethylene, a natural hormone produced by some fruits as they ripen, promotes additional ripening of produce exposed to it. Ethylene gas is produced in most plant tissues and is an important factor in initiating the ripening process (Irtwange, 2006) as shown Figure 2. Ethylene "producers"should not be stored with fruits, vegetables, or flowers that are sensitive to it. The result could be loss of quality, reduced shelf life, and specific symptoms of injury. The

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ethylene burst is the key event signaling the onset of ripening in climacteric fruits such as tomato. Manipulation of ethylene biosynthesis and signaling has resulted in varieties with delayed ripening (Vicente *et al*., 2007).

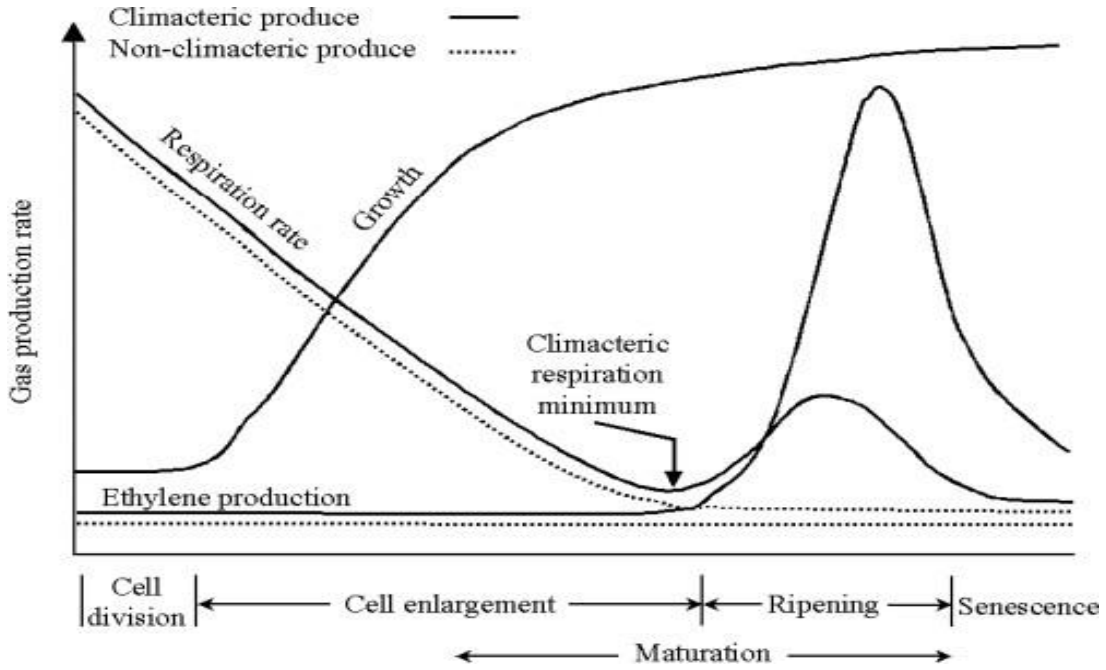

Figure 2. Gas production rate as a function of developmental stage (Nicolai et al., 2005

2.2 Shelf life of tomato

Shelf life quality under specified storage condition. Fruits shelf life during storage is an important feature from a producers and a distributor's point of view, allowing the determination of risks arising from the loss of commercial value of fresh fruit in tradeturnover (Radajewska & Borowiak, 2002). Shelf life of a commodity is governed by several factors such as variety, stage of maturity, respiration rate, storage temperature, relative humidity, packaging system, etc. Storage temperatures and relative humidity affect the storagelosses to a great extent. Proper control of temperature and relative humidity is the key to prolong the storage life and marketable quality. The shelf life is a period of time which starts from harvesting and extends up to the start of rotting of fruits (Mondal, 2000).

2.3 Edible film coating

Edible coatings and films can preserve appearance, firmness, moisture and increase the shelf life of fruits because of their barrier properties against moisture and gas transmission, lipid oxidation and controlling enzymatic activities and microbial spoilage (Brown *et al*., 2018; Senturk Parreidt *et al*., 2018). Edible coatings modify the atmosphere around fruits; changethe normal gas composition inside the fruit, delay respiration rate and production of ethylene thus limiting

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physiological decay of fruits (Maringgal *et al*., 2020). Furthermore, a study has shown that edible coatings containing antimicrobial agents, for instance, organic acids, essential oils from plants and polypeptides inhibit the growth of microorganisms (Nandane *et al*., 2017). Edible coatings can reduce the enzyme activity, minimise browning reaction andthe softening of the texture. In addition, it has the potential to maintain the natural volatile flavour compounds and color components (Sapper & Chiralt, 2018). The edible coatings protect the food products against various microbial contaminants and reduces deterioration effect (Dong *et al.*, 2020) prolongs storage period (Grosso *et al.*, 2020; Hasan *et al*., 2020) minimise lipid oxidation and moisture loss of food products (De Pilli, 2020; Kazemian- Bazkiaee *et al*., 2020).

2.3.1 Beeswax

A natural wax produced by honeybees (C*era alba*) is beeswax. Such wax, which is solid at room temperature, is composed of mixed esters of long chain alcohols (C26-32) and fatty acids and hydroxyl fatty acids of chain length of 16-26 (Spiess, 1992). Beeswax is used in the food as a glazing agent, stabilizer, texturizer and carrier. A total production of 66,173 tonnes of beeswax was produced in 2014 in the world (FAO, 2006). Table 3 shows characteristics of beeswax, including its melting temperature, peroxide value and solubility. Beeswax can be white and yellow.

Table 3. Characteristics of beeswax (Adapted from FAO, 2006).

Characteristic	**Range**
Melting range	62-65ºC
Acid value	17-24
Peroxide value	No more than 5
Saponification value	87 -104
Solubility	Insoluble in water; sparingly soluble in ethanol; very soluble in ether.

2.3.2 Functional properties of chitosan

The physicochemical and biological properties of chitosan justify its introduction in food formulations since it could improve nutritional, hygienic and/or sensory properties, because of its emulsifying, antimicrobial, antioxidant and gelling properties, while also acting as a functional fiber (Casariego *et al*., 2008). Chitosan is not digestible by the human body, and so ingesting it does not increase calorie intake. Apart from its antimicrobial effect, chitosan is also used in food as clarifying agent in apple juice; antioxidant in sausages; enzymatic browning inhibitor in apple and pear juices and in potatoes and antimicrobial agent in minimally processed foods. As it forms semipermeable films, chitosan can modify the internal atmosphere (by altering the permeability to water, oxygen and carbon dioxide), thereby decreasing the transpiration loss, reducing respiration

rate and delay ripening in fruits, maintaining the quality of harvested fruits and reducing mold growth. Chitosan is good for fresh-cut fruits and vegetables when it is in close contact with the tissue. Chitosan could be an ideal preservative coating because of its film forming properties, biochemical properties, inherent antifungal properties and elicitation of phytoalexins (Thumula, 2006).

The functional properties of chitosan-based films can be improved by combining them with other hydrocolloids and film-forming materials. In this sense, chitosan/pectin laminated films were developed by interacting cationic groups of chitosan with the anionic groups of pectin. Water vapor transmission rates could be decreased by combining chitosan with two thermally gelatinized corn starches. In order to improve water barrier properties, lipid compounds such as fatty acids, natural waxes, surfactants and resins are frequently incorporated into hydrocolloid based films. For example, saturated fatty acids and fatty acid esters were added to chitosan-based films, obtaining a higher resistance to water vapor transmission when lauric and butyric acids were used; Vitamin E was incorporated into the chitosan matrix obtaining a significant decrease in the water vapor permeability, an increase of opacity and a significant reduction in the tensile strength of the composite films. The effect of adding some saturated fatty acids, such as palmitic and stearic, has also been investigated. In general, the addition of oleic acid into the chitosan matrix leads to a significant increase in gloss and translucency and a decrease in the tensile strength, elongation at break and elastic modulus of the composite films (Vargas et al., 2009a). Chitosan based polymeric materials can be formed into fibers, films, gels, sponges, beads or even nanoparticles (Dutta et al., 2008). Chitosan films have a selective permeability to gases (CO_2 and O_2). However, the fact that they are highly permeable to water vapor limits their uses which are an important drawback since an effective control of moisture transfer is a desirable property for most foods (Vargas *et al.*, 2009a).Chitosan is not water soluble, but it forms viscous solutions in various organic acids. Acetic acid has often been used as a solvent for the production of chitosan films, but it imparts a strong acidic flavor and aroma to the foods in which it is used. Lactic acid has been used instead of acetic acid because it has a weaker acidic flavor and aroma, which was found using a trained sensory panel that compared chitosan films produced with both acids (Casariego *et al*., 2008). This makes it particularly suitable for the formulation of edible coatings, for maintaining the quality and extending the shelf-life of fruits and vegetables such as citrus, peach, pear, kiwifruit, strawberries, tomatoes and apples. The effects of chitosan coating on the storage life of fresh-cut products such as strawberries, carrot, mango, cantaloupe, pineapple, and mushroom were investigated (Vargas *et al*., 2009a, b; Campaniello *et al*., 2008; Eissa, 2007; Sangsuwan *et al*., 2008).

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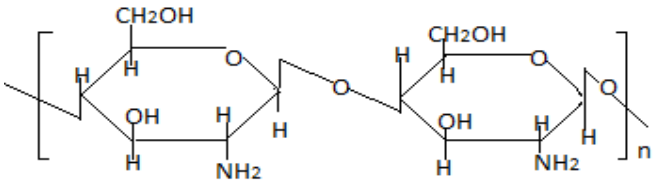

Figure 3: Structure of Chitosan

2.3.3 Pectin

Pectin is a group of polysaccharides which is derived from plant; it is naturally found in fruits and vegetables. Pectin is good for low moisture fruits and vegetables but is not a good moisture barrier (Yapo, 2011). It is a heterogeneous group of acidic polysaccharides. It is commonly found in peel of citrus fruits and apple pomace. The structure of pectin polysaccharide are very complex, are made up of β-1, 4-liked-galactouronic acid residues (Dhanpal *et al*., 2012). Pectin is a complex polysaccharide; it composed from 1, 4- linked d-galactouronic acid residue. HMP (High Methoxy Pectin) are excellent pectin compound for producing good film and coating. The mixture of citrus pectin and high amylose starch provided a pliable film and coating. These are stable at the temperature of 180˚C; pectin is dissolved in poly vinyl alcohol (Fang and Hanna, 2000).

2.4 Tomatoes Health Benefits

Tomatoes can make people healthier and decrease the risk of conditions such as cancer, osteoporosis and cardiovascular disease. People who ate tomatoes regularly have a reduced risk of contracting cancer diseases such as lung, prostate, stomach, cervical, breast, oral, colorectal, esophageal, pancreatic, and many other types of cancer. Some studies show that tomatoes and garlic should be taken together at the same time to have its cancer preventive effects (Bhowmik *et al*., 2013).

Tomatoes contain all four major carotenoids: alpha- and beta-carotene, lutein, and lycopene. These carotenoids may have individual benefits, but also have synergy as a group (that is, they interact to provide health benefits). The red pigment contained in tomatoes is called lycopene. This compound appears to act as an antioxidant, neutralizing free radicals that can damage cells in the body. Tomatoes contain all three high-powered antioxidants: beta-carotene (which has vitamin A activity in the body), vitamin E, and vitamin C. Lycopene is a vital antioxidant that helps in the fight against cancerous cell formation as well as other kinds of health complications and diseases. Free radicals in the body can be flushed out with high levels of lycopene, and the tomato is so amply loaded with this vital antioxidant that it actually derives its rich redness from the nutrient (Bhowmik *et al*., 2013).

Lycopene is a carotenoid that can only be synthesized by plants and not by animals. It is an acyclic isomer of β-carotene, but without vitamin A activity. It is a straight chain hydrocarbon, which is highly

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unsaturated and contains two non-conjugated and 11 conjugated double bonds. Recently, it is getting more attention due to its antioxidant properties. In contrast to other carotenoids, it is present in a very limited number of fruits and vegetables. The most common sources of lycopene are tomato, watermelon, pink guava, pink grapefruit and apricot. Tomato and processed tomato products are a good source of lycopene. Its quantity is affected by tomato variety and ripening stage (Nasir *et al*., 2015). Lycopene is poorly absorbed in its natural trans form that is present in raw tomatoes. Recently, many studies have shown that heat processing of tomato into various products like tomato paste, ketchup and sauces induce isomerization of lycopene from trans to cis configuration and hence increases its bioavailability. A negligible increase in plasma lycopene level was observed after consumption of unheated tomato juice. However, when oil was mixed with heated tomato juice and consumed, then plasma lycopene concentration was found to increase after 24-48hr of ingestion. Lycopene absorption and its bioavailability depend upon fat content of the meal, processing of lycopene containing food and heat induced isomerization (Nasir *et al*., 2015). Lycopene is a naturally occurring substance found in large amounts in tomatoes. Lycopene acts as an antioxidant and has an influence in reducing the risk of various chronic diseases including cancer. The lycopene content in tomatoes increases in the body if the tomatoes are processed first such as into juices, sauces, and so on (Tampubolon, 2019).

2.5 Quality attributes of tomato

The quality of tomato is determined by color, appearance, flavor and firmness. Color of tomato is very important in determining its quality.

2.5.1. Weight loss (PWL)

Quality of most fruits and vegetables is affected by weight (water) loss during storage, which depends on the temperature and relative humidity conditions (Perez *et al*., 2003). Respiration is a central process in living cells that mediates the release of energy through the breakdown of carbon compounds and this gives an indication of the overall metabolism of the plant part which utilizes the plant product as its substrate thereby leading to weight loss and shriveling. The respiration rate can be used to predict the loss of weight from a produce. The weight loss due to transpiration is the main cause of postharvest losses and poor quality especially in such leafy vegetables as lettuce, chard, spinach, cabbage and green onion (De Ell *et al*., 2003).

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2.5.2 Appearance

Appearance is of vital importance for consumers purchase decision. The appearance of tomatois greatly influenced by the presence and magnitude of defects. Produce with uniform size, shape and color and absence of defects are expected by consumers. Among these, color contributes more to the assessment of quality than any other single appearance factor (Valero &Serrano, 2010).

2.5.3 Flavor

Flavor is a complex sensation linked to perception of the tasts and aroma of many compounds. It is an additional key parameter that determines the choice of selection of a fruit or vegetable. When a fruit/vegetable has not reached or has exceeded its "flavor life", the main consequence is a dissatisfaction and lower demand by consumers (Valero& Serrano, 2010). Aroma substances are volatile compounds that are perceived by the odor receptor sites of the olfactory system at the nasal cavity. After harvest, fruit and vegetables can generate either pleasant odor or off-odor depending on types of product. The appearance and sensation of off-flavor are highly associated with over maturation and the accumulation of the ethanol fermentation products such as acetaldehyde and ethanol). Flavor quality of tomatoes is largely determined by the sugar (estimated by soluble solids content) and acid composition of the fruit (Moretti *et al*., 1998).

2.5.4 Firmness

Firmness is a critical quality character because it determines whether or not fruit can be transported or shipped to distant markets without deteriorating. Tomato fruit soften as they develop from im-mature green to full red color (Hanson, 2001). The firmness is a criterion often used to evaluate fruit quality as it is directly related to fruit development, maturity, ripening and storage potential. Firmness is considered as principal characteristics of fruit, important for quality, harvest, maturity, and storage and shelf- life. High quality fruits have a firm appearance, uniform and shiny color, without signs of injury, shriveling or decay (Sargent &Moretti, 2002).

2.5.5 Color

Color is usually the first characteristic that a consumer observes in evaluating the quality of fruit and vegetables with predetermined expectation of flavor and taste. Tomato color, a factor for general appearance is another important factor in the consumer preference of tomatoes (Batu, 2003). Color in tomato is the most important external characteristic to assess ripeness and postharvest life, and is a major factor in the consumer's purchase decision. Red color is the result of chlorophyll degradation as well as synthesis of lycopene and other carotenoids, as chloroplasts are converted into chromoplasts (Fraser *et al*., 1994).

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2.5.6 pH

The term pH is used to express the concentration of free H_3O+ in a sample and results from dissociation of the acids present. pH is defined as the negative logarithm of the hydrogen ion concentration, and can span a range of 14 orders of magnitude. pH is the measure of the strength of the acids. According to Hanson (2001), the pH values of tomato are in the range of 4 - 5.

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3 MATERIALS AND METHODS

3.1 Experimental location

The experiment was conducted in Addis Ababa University, Center for Food Science research laboratory, Ethiopia public health institute (EPHI), Kolfe industrial college (KIC), Addis Ababa science and technology university (AASTU) research laboratory.

3.2 Sample packaging and transportation

Maximum care was taken to minimize mechanical damage during transportation and handling. The sample were packed in corrugated carton and transported in mid night days to reduce the excessive environmental heat during transportation from Melkasa Agricultural Research center to Addis Ababa university center for food science research laboratory**.**

3.3 Experimental design

A Completely Randomized Design (CRD) was used to study the effectiveness of the edible film on microbiological safety, retention of sensory attributes and shelf life stability.

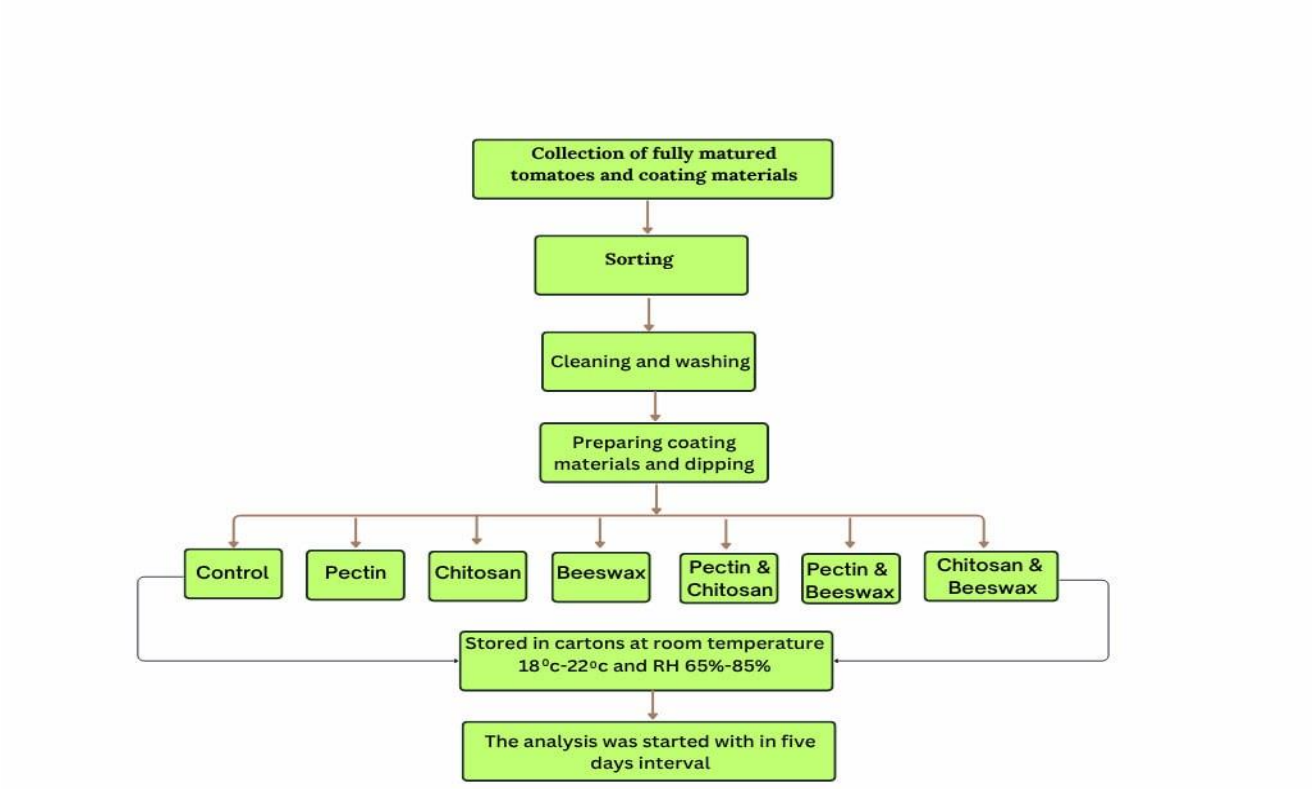

Figure 4**:** Schematic illustration of the experimental design (by Visio 2010 software)

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3.4 Material

Fully matured tomato samples (Galilea hybrid) were collected from Melkassa Agricultural Research Center and chemicals from local suppliers (Neway and Atomic chemical supplier PLC). Sample tools, Hygrometer meter, and Beeswax from local market, Pectin from Upper Awash Agro Industry Enterprise (UAAIE), Chitosan from Clean Water Chemicals Shanghai co.,LTD, China.

3.5 Experimental layout

The experiment was conducted in seven experimental run with using three different edible film coating materials in combined and with alone as shown table 4. The control was not coated with edible film coating materials. The sample were stored for several days with regularly checked the quality tests in five days interval and the different coated material have showed different storage shelf life depend on the coating materials effectiveness.

Table 4. Experimental layout

S/N	Treatment	Response	
		Storage day	Parameter Test
1	Control	Quality test every five days	Physiochemical (WL, pH,TSS, Acidity, Titratable acidity, Acid ratio, Total sugar, Reducing sugar, non-reducing sugar, lycopene , and Vitamin C) Nutritional composition analysis (Moisture, Protein, Fat, Crude fiber, Ash , and Carbohydrate) Microbiological testes (Total plate count, Yeast and Mould, and Coliform count)
2	Chitosan		
3	Beeswax		
4	Pectin		
5	Chitosan with pectin Zhang *et al*.,(2017), Jin *et al*.,2018 ratio (1:1)		
6	Chitosan with beeswax (Rodriguez Martinez, E. N. (2017)) ratio (1:1)		
7	Beeswax with pectin (Rodriguez Martinez, E. N. (2017)) ratio (1:1)		

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3.6 Sampling and sample preparation

To maintain the uniformity of the experimental materials, uniform stage of maturity, free from pest and disease, injuries, bruisesand blemishes was selected (Figure 5). A total of 21 kg of fully matured tomato was collected. Three coating materials (Beeswax, pectin and Chitosan) we re obtained from the chemical supplier. also, other chemicals used for analysis were obtained from local suppliers they were analytical grades.



Figure 5: Tomato sample used in the experiment

3.6.1 Preparation of chitosan solution

A Chitosan solution was made using the methods indicated by Wongmetha and Ke(2012). Briefly, 5 g of chitosan powder was dispersed in 850 ml of distilled water to which 50 ml of glacial acetic acid was added to dissolve the chitosan. The pH of the solution was adjusted to 5 with 1 mol/L NaOH, and 1 ml of Tween 80 solution to improve wettability.

3.6.2 Preparation of Beeswax solution

Beeswax emulsion was prepared following the methods indicated in Efendi and Hermawati (2010). Beeswax (76.8 g) was placed in 2 litter container and melted at 70° C, heated continuously to attain a temperature of 80- 90 ^{o} C. Oleic acid (12.8 ml) was added to the melted wax followed by the addition of 25.6 ml triethanolamine (TEA) with a constant stirring. Then 524.8 ml of distilled water (pre-heated at the same temperature of 80-90 ^{o} C) was added slowly, stirring for 5 minutes and air dried. The prepared emulsion was cooled and stored at ambient temperature in sealed container before use.

3.6.3 Preparation of pectin solution

Commercially, available pectin (30 g) with 50% degree of esterification would dissolved in 1000 ml warm water (40°C), whilst stirred with magnetic stirrer to prepare 3% (w/v) pectin solution and allowed to homogenized with moderate stirring until the solute completelydissolved, as indicated in Felix and Mahendran (2009).

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3.6.4 Application of coating treatments

Fruits were uniformly dipped in each solution when the solutions reached room temperature (18 ^{o}C -22°C). Fruits were dipped for 4–5 min to ensure uniform coating of the whole surface. Meanwhile control fruits were dipped in distilled water for the same duration and excess water/solution from the fruits was removed and air dried for 3 h at room temperature. After being air-dried, the fruits were stored in cartons at temperature of 18°C- 22°C and relative humidity of 65%-85% for quality and shelf life assessments. The data were recorded before treatment (day 0) and in 5 days interval for all physicochemical parameters for 35 days (Abebe *et al*., 2017).



Figure 6: tomato sample during dipping



Figure 7: Tomato after dipping in store at room temperature

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3.7 Physicochemical property of tomato

3.7.1 Weight loss (%)

Weight loss in the samples was determined by weighing tomatoes in five days interval. For the determination of weight loss during regular air and coated storage, three tomato fruits was marked at the start of experiment from each treatment and kept separate for periodic weighing using an electronic balance (Park *et al*., 1994). The physiological weight loss was calculated for each interval and converted into percentage of initial weight. The cumulative weight loss was expressed in percentage with respect to different treatments (Tefera *et al*., 2007). The percent weight loss was calculated as follows:

$$\text{Weight loss (\%)} = \frac{\textit{initial weight} - \textit{weight at the end of storage}}{\textbf{initial weight}} \text{ x } 100 \qquad (1)$$

3.7.2 pH of tomato

The pH of tomato juice was measured by using a digital pH meter. The samples were randomly taken from each treatment unit and the pH values of the juice were measured according to (AOAC, 2005) method. Tomatoes were crushed and made into juice. Then, the pH meter was standardized with pH 4.0 and 7.0 buffer solutions. After standardization, the pH of each juice sample was measured by using digital pH meter.

3.7.3 Acidity

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

$$\% \text{ Acid} = (\text{NaOH consumed}) \text{ x } 0.007 \text{ x } 100 \qquad (2)$$

Where, 0.007 is the conversion factors for tomato produces

3.7.4 Total Soluble Solids (Brix)

Total soluble solids were determined according to AOAC (2000) using a digital refractometer at room temperature. The refractometer was calibrated with distilled water and 3 drops of extracted juice from the homogenized representative sample were placed on the prism of the refractometer and the reading was taken directly. The determinations were done in triplicate and the mean values were recorded using a brix. After each test, the prism plate was cleaned with distilled water and wiped with soft tissue for subsequent measurement.

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3.7.5 Titratable acidity

Titratable acidity was determined according to the procedure of AOAC (2000). Fruits were crushed and made into juice, 5 ml of tomato juice diluted in 25 mL of distilled water, two drops of phenolphthalein indicator and titrated with 0.1N sodium hydroxide (NaOH). The titratable acidity was expressed as percentage of citric acid equivalent, since this organic acid is a predominant acid in the fruit. Titratable acidity was determined using the following equation.

$$\%\text{Acid} = \frac{(\text{ml NaOH})(\text{N of the base in mol per liter})(0.0064)}{\textit{Sample volume in ml}} \times 100 \quad (3)$$

Where, 0.1 is the normality of NaOH (N) or 1ml 0.1N NaOH is equivalent to 0.0064g citric acid.

0.064 is the conversion factor for citric acid

3.7.6 Total Soluble Solids/Acid ratio

Total Soluble Solids (TSS)/acid ratio were calculated for all the samples the using following formula:

TSS/Acid ratio =TSS/ Total Acid contents

3.7.7 Total Sugars (%)

Total sugars were determined by taking 25 gram of fruit juice meticulously standardized using distilled water. Volume was prepared to 250 ml and 5 ml lead acetate was added to it. The precipitate was strained into a flask comprising 5 ml potassium oxalate. Contents were shaken and again filtered, then, 100 ml of filtrate was in a 250 ml flask, and a few drops of concentrated HCl. were added to it. The filtrate was retained overnight to acquire the hydrolysis of sugars completely. Leftover HCl was neutralized by saturated NaOH solution, with the help of phenolphthalein indicator. The boiling mixture (5 ml each of Fehling's A and B solution) was titrated against a hydrolyzed aliquot in a burette containing methylene blue indicator to attain brick red color which is considered as the end point.

$$\text{Total sugars (\%)} = \frac{\text{Fehling factor x volume made up x 100 Titre}}{\text{value x sample weight}} \quad (4)$$

3.7.8 Reducing Sugars (%)

To estimate reducing sugars were determined by the volumetric method of Lane and Eynon(1923) , an-hydrolyzed but lead free and clarified solution was titrated with bubbling solution containing 5 ml each of Fehling A and Fehling B using methylene blue as an indicator (AOAC, 1984). The endpoint was specified by brick red color and reducing sugars were calculated and expressed as percent fresh weight of fruit juice.

$$\text{Reducing sugars (\%)} = \frac{\text{Factor x Dilution}}{\text{Titre value} \times \text{wt.or vol.of sample}} \times 100 \quad (5)$$

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3.7.9 Non-reducing Sugars (%)

The non-reducing sugars were determined by using the following formula (Hortwitz, 1960).
Non-reducing sugars (%) = Total Sugars (%) – [Reducing sugars (%) X 0.95 factor].

3.7.10 Lycopene Content

Lycopene content was measured using a spectrophotometer (Thermo Fisher Scientific, Madison, WI, USA). A frozen sample of (0.5 g) was homogenized in 1 mL of distilled water. The homogenate was further diluted with 2:1:1 of 20 mL of n-hexane, acetone, and ethanol, respectively. Then, the flask was placed in crushed ice and shaken for 1 h. The mixture was centrifuged at 15,000 rpm for 20 min. Afterwards, 3 mL of distilled water was added to each sample, which was agitated for 2 min and left at room temperature for a few minutes until phase separation was achieved. Each sample was then read using the spectrophotometer at 503 nm. The lycopene content of the samples was then expressed as mg kg−1 of fresh weight according to the method reported by (Fish *et al.* (2002). The solution was then separated into distinct polar and non-polar layers and filtered using filter paper (Whatman grade 42). Lycopene concentration was estimated by measuring the absorbance of the extract at 503 nm by using a UV-VIS Spectrophotometer using hexane as a blank (Ranveer *et al.* 2013). The lycopene concentration was calculated using its specific extinction coefficient (E1%, 1 cm) of 3120 in hexane at 503 nm. The lycopene concentration was expressed as mg/kg fresh tomato, and calculated by the following formula:

Lycopene (mg/kg fresh wt.) = $\frac{(A503\times 537\times 2.7)}{(0.5\times 172)}$ Where; 537 g/mole is the molecular weight of lycopene, 2.7 is the volume (mL) of the hexane layer, 0.5 g is the weight of sample added, and 172 mM−1 is the extinction coefficient for lycopene in hexane.

3.7.11 **Vitamin** C

Ascorbic acid content was determined by spectrophotometric method (Mohammed *et al.*, 2009). Sample preparation 5 ml of each juice sample was transferred into a 100ml beaker homogenized by using 25 ml acetic acid solution with shaken, 4-5 drops of bromine water were added until the solution became colored, Then a few drops of thiourea solution were added to it to remove the excess bromine and thus the clear solution was obtained. Then 2, 4-Dinitrophenyl hydrazine solution was added thoroughly with all standards and also with the oxidized ascorbic acid. Then, the solution was completed and brought up to the mark with acetic acid. The absorbance for all samples has been measured using a UV-visible spectrophotometer to determine the concentration of ascorbic acid in the juice.

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3.7.12 Nutritional composition (Proximate compositional analysis)

The nutritional value of the samples were analyzed for chemical composition (moisture,proteins, fat, crude fiber (Vaccum pump method),carbohydrates and ash) using the AOAC procedures (AOAC, (2005)). The crude protein content of the samples was estimated by the Kjeldahl method using a conversion factor of N × 6.25; the crude fat content was determined by extracting a known weight of powdered sample with petroleum ether, using a Soxhlet apparatus; the ash content was determined by incineration at 550±15 ºC for five hours using muffle furnace. Total carbohydrates were calculated by difference.

I Determination of moisture content

The moisture content of each sample was determined using AOAC 2005; a clean and dry crucible was weighted and 5g of each sample was added to it. The crucible was placed in a drying oven (Genlab, OV/125/SS/F/DIG/A, UK) at 105°C for 3 hours. After 3 hours it was cooled in a desiccator and measured. The sample was again placed in the drying oven for 1 hour and then cooled in a desiccator and measured; this was repeated until a constant weight was obtained.

$$Mosture\ content\ (MC, \%) = \frac{W2-W3}{W2-W1} * 100 \quad (6)$$

Where: W1- weight of the crucible

W2- weight of the crucible when sample is added

W3- the final weight

II Determination of crude fat content

The fat content of each sample was assessed using the Soxhlet method, following AOAC 2005 standards. Initially, 2g of each sample was accurately weighed onto fat-free cotton and placed inside an extraction thimble. The extraction cylinder, containing the thimble with the sample, was weighed precisely before adding 50ml of hexane. Subsequently, the extraction cylinder, with the sample-laden thimble, was heated on a heating mantle at 80°C for 4 hours to facilitate extraction. After the 4-hour extraction process, the extraction cylinder was transferred to a drying oven set at 70°C for 30 minutes to eliminate any residual moisture. Finally, the cylinder was placed in a desiccator to cool to ambient temperature before the final measurement was taken.

$$\text{Crude fat, percent by weight}(\%) = \frac{W2-W1}{W} * 100 \quad (7)$$

Where: W1=weight of the extraction flask (g)

W2= Weight of the extraction flask plus the dried crude fat (g)

W3=Weight of sample (g)

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III Determination of crude fiber content

The crude fiber of each sample was determined according to AOAC 2005; 12.5% of NaOH and 12.5% of sulphuric acid were prepared in a 1000ml volumetric flask. 1g of each sample was placed in a beaker and 200ml of sulphuric acid was added. Then the sample was placed on a hot plate and boiled for 37 minutes, after that the acid was drained using the vacuum pump. The sample was cooled for 5 minutes and washed three times by using distilled water. The sample was again placed in a beaker and 200ml of 12.5% NaOH was added and boiled on a hot plate for 37 minutes. After 37 minutes the base was drained using the vacuum pump.

The residue was placed in a dry and clean crucible and set in the oven at 130°C for 2 hours. After 2 hours the crucible was transferred into a muffle furnace for 3 hours at 550°C after being measured. After 3 hours the crucible was cooled at room temperature and weighted.

$$\text{Crude fiber (\%)} = \frac{W2-W3}{W1} \quad (8)$$

Where: W1- weight of sample

W2- weight of crucible plus sample after drying in oven

W3- weight of crucible plus sample after ashing

IV Determination of ash content

The ash content of each sample was analyzed following AOAC 2005 standards. Initially, 2.5g of each sample was meticulously measured into pristine porcelain crucibles. Following this, the samples were subjected to charring on a hot plate until smoke emissions ceased, after which they were transferred into a muffle furnace (CAEBOLITE, CSF 12/13, England) set at 550°C for 5 hours.

Upon completion of the 5 hours, characterized by the attainment of a clean, white appearance indicative of complete ashing, the crucibles were allowed to cool to room temperature. Subsequently, the ash content was accurately weighed to ascertain the precise measurement.

$$\text{Ash content (\%)} = \frac{M3-M1}{M2-M1} * 100 \quad (9)$$

Where (M2-M1) is sample mass in gram on dry basis and (M3-M1) mass of ash in gram.

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V Determination of crud protein content

Crude protein was determined using the three steps known as Digestion, Distillation and Titration (AOAC 2005).

Digestion: Initially, 0.5g of the sample was carefully introduced into a digester flask, followed by the addition of 6ml of a solution comprising sulphuric acid, hydrogen peroxide, and a mixture of copper sulphate and potassium sulphate. Subsequently, the flask underwent digestion within a specialized machine, maintained at 370°C, for a duration of 4 hours.

Distillation: Following the digestion process, the digester flask was transitioned into the distillation apparatus. The machine parameters were adjusted to introduce 25ml each of 40% sodium hydroxide, boric acid, and distilled water, along with an appropriate indicator solution. Distillation proceeded until the total volume reached 250ml, marking the completion of the distillation phase.

Finally titration process was done by using 0.1N HCl till it reached reddish colour.

$$\text{Nitrogen (\%)} = \frac{\mathbf{VHCl}\text{ in L} \times \mathbf{NHCl} \times 14 \times 100}{W} \quad (10)$$

The % of Nitrogen was converted to % of protein by using appropriate conversion factor by multiplying the result by 6.25.

3.7.13 Disease incidence

Postharvest disease incidence and severity were assessed during the storage period. The infection of fungal spoilage and rotten fruits was identified using different approach such as looking at the appearance of decayed fruits. Following the identification of infections, disease incidence was calculated as the number of infected fruits showing any single symptom out of total number of tomato fruits sampled (Ogbo and Oyibo, 2008).

$$\text{Disease incidence (I) (Frequency)} = \frac{Number\ of\ fruits\ infected}{\text{Number of fruits assessed}} * 100 \quad (11)$$

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3.8 Microbiological analysis

3.8.1 Total viable count

One gram sample of paste was transfer to 99 ml of distilled water and the mixture were homogenized with continuous shaking for several minutes. Then, one ml of the sample solution was dilute in another tube with 9 ml distilled water. The total viable count per gram of paste was carryied out following the method of American Public Health Association (APHA 1967). FDA BAM Chapter 3: Aerobic Plate Count, January 2001. https://www.fda.gov/food/laboratory-methods-food/bam-chapter-3-aerobic-plate-count)

3.8.2 Yeast and mould count

The yeast and mould strains in the different samples were cultured on Potato Dextrose Agar (PDA) medium, and incubated at 35°C for 48 hours, and then the yeasts and moulds were counted. Plates containing between 30 and 3000 colonies were counted as colony forming units (c.f.u.) per g of sample. Using Pour Plate Method, the sample was taken and serially diluted to 1:10, 1:100 and 1:1000. For yeast and mould, total plate count was use. Diluents (1ml) of were taken from each and put on a sterile Petridish, poured potato dextrose agar and mixed with the sample, then incubated and the colony was counted (APHA, 1976). (FDA BAM Chapter 18: Yeasts, Molds and Mycotoxins, October 2020. https://www.fda.gov/food/laboratory-methods-food/bam-chapter-18-yeasts-molds-and-mycotoxins)

3.8.3 Coliform count

For coliform count, 1ml of diluents was inoculated into a separate tube of an all-purpose broth medium for each serious dilution. Incubated for 48h at 35°C and after incubation, the pattern of positive and negative tubes was noted, and a standardized MPN. The most probable number (MPN) is a method of calculating the number of microorganisms from the growth of microorganisms in a specific liquid medium in a series of tubes to obtain qualitative data (MPN/ml/g). The most probable number is a multilevel dilution test used to measure contamination of target microorganisms with an estimate of the Indonesian national standard with the 012332.1 series describing MPN as a method for calculating the number of microbes using liquid medium in test tubes (Musdalifa, 2018). The smaller the MPN value, the higher drinking water quality and fit for drinking (Selvy *et al*., 2015). (New York State Department of Health: Coliform Bacteria in Drinking Water, 2023.
https://www.health.ny.gov/environmental/water/drinking/coliform_bacteria.htm)

3.9 Sensory Analysis

Coated and uncoated stored tomatoes were evaluated based on nine points of hedonic scales for sensory attributes such as color, appearance, firmness, flavor and overall acceptability.

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Samples of the different tomato products were coded and subjected to sensory evaluation by using 11 trained panelists comprised of MSc students in Food science and nutrition. The panelists were asked to assess each sample for its flavor, color, appearance, firmness and overall acceptability in a comfortable room with sufficient light and fresh air. Then panelists were asked to rate evaluation variables according to 9 point Hedonic scale. The results obtained from the panelists were converted to scores ranging from: like extremely (9) to dislike extremely (1). The products were presented to each panel including a control sample plus one or more test samples. The panels were requested to rate the size of the difference between each sample and the control by providing a scale for this purpose.

3.10 Data Analysis

The results of laboratory analysis were expressed in mean ± standard deviation and sensory evaluation results were expressed in descriptive statistics and analysis of variance (ANOVA) was used to compare the means. Significant differences between treatment groups were compared by using Duncan's multiple range test (DMRT) at $p<0.05$. Data was analyzed using Statistical Package for the Social Sciences software (SPSS) version 27.

3.11 Ethical consideration

The study was conducted after obtaining approval for the protocol from Addis Ababa University College of Natural and Computational Sciences Institutional Review Boards (IRB/06/2015/2023). In addition, a support letter from the Center for Food Science, CNCS, and Addis Ababa University. The study's overall objective, as well as possible risks and benefits to the participating volunteers was clearly presented. The data from the participant was obtained using a written document. All the information collected from participants was kept confidential, so that personal information was not disclosed. Benefits and the risk of the study: generally , the study output provided helpful information to the participate in giving clear description on the coating methods of tomato storage and shelf life, you were receive which coating types better to the effectiveness of shelf life and which coating more important storage and extending shelf life tomato.

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4 RESULTS AND DISCUSSION

4.1 Physicochemical property of tomato

4.1.1 *Physiological weight loss*

Table 5 summarizes weight loss in coated and uncoated tomato samples before treatment and over 35 days of storage at various intervals. We found that coating decreases the weight loss of samples compared to uncoated samples, along with a prolonged storage period. Weight loss was significantly increased in a prolonged storage period, and the highest weight loss occurred in chitosan with wax combination coatings (25.55%) at 30 days of storage (Table 5). Observations during storage of tomatoes in the table below revealed that the physiological loss in weight was increased for both coated and uncoated ones as the storage period progressed. The physiological loss in weight was maximum in case of the uncoated samples or control whereas coated samples showed minimum physiological loss in weight followed by wax coated, pectin with wax coated, pectin coated, pectin with chitosan coated and chitosan with wax coated tomatoes respectively from the minimum to maximum physiological weight loss . As showed from the table tomatoes coated pectin with wax has high storage day with relatively physiological losses as compared with other treatments. Whereas the control or uncoated tomatoes showed that higher physiological losses with in short storage day. At the end of 30 days of the storage period, the weight loss percentages for a combination of chitosan with wax (1:1) pectin with chitosan and pectin with wax (1:1) coated were recorded as 25.55 %, 22.66 %, 17.81%, 14.04 % and 9.47%, respectively. For example, pectin and pectin with chitosan film coated fruits lost less weight than the other coated and uncoated tomato fruits shown below (Table 5). Wax coated tomatoes showed that minimum losses these may due to high impermeability of wax coated tomatoes and modified the gas compositions inside the fruit and slow the rate of respiration rates. Weight loss in tomatoes is mainly associated with the loss of water by transpiration and loss of carbon reserves due to respiration (Sogvar *et al*., 2016).

The use of edible coatings in tomatoes can reduce weight loss by 0.4–16% compared with the uncoated tomatoes (Kibar & Sabir, 2018). The extent of weight loss varies with the type of edible coating, storage temperature, relative humidity, and the duration of storage. This finding is consistent with Getinet et al. (2008), who found that the greatest weight loss was recorded. However, mature green uncoated fruits weighed significantly less than covered fruits at the light red stage. However, when storage time rose, weight loss increased at varying rates, depending on whether coating films were present.

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The probable mechanism of this greatest weight loss could be the coating material, which acts as a semi-permeable barrier against oxygen, carbon dioxide, moisture and solute movement and thereby reduces rate of respiration, water loss and oxidation reaction (Ghosh *et al*., 2015; Mani *et al*., 2017). Moreover, moisture loss and gas exchange from fruits are typically controlled by epidermal layers equipped with guard cells and stomata. The layer generated on the fruit's surface acts as a physical barrier, reducing moisture migration (Togrul and Arslan, 2004). This barrier property also lowers oxygen availability and uptake by the fruit during the respiration process, slowing the rate of respiration and associated weight (Abbasi et al., 2009). Regarding the individual coatings, the weight loss in the chitosan-coated tomato sample was higher (23.13%) than wax and pectin at the 25 days of storage. Furthermore, minimum weight loss was observed in wax coated tomato samples.

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Table 5: Weight loss, pH, and TSS coated and uncoated tomato analysis.

Par.	Trt.	Storage day							
		0	5	10	15	20	25	30	35
WL (%)	Control	-	2.82 ± 0.48^{d}	5.59 ±1.04 ^{b}	11.90 ± 0.8^{d}	-	-	-	-
	Wax	-	1.28 ± 0.66^{b}	4.26 ±0.94^{a}	5.62 ±1.05^{a}	6.83 ±1.13^{a}	8.27 ±1.06^{a}	9.47 ± 0.64^{a}	-
	chitosan	-	1.26 ± 0.50^{b}	4.72 ±1.07^{a}	7.27 ± 2.24^{bc}	11.09 ± 3.12^{bc}	23.13 ± 6.30^{d}	-	-
	Pectin	-	1.18 ± 0.85^{a}	5.38 ±1.68^{b}	8.28 ± 2.23^{c}	11.39 ± 2.90^{bc}	15.09 ± 3.10^{bc}	17.81 ± 2.71^{c}	-
	P*C	-	1.18 ± 0.12^{a}	5.64 ± 1.22^{b}	8.95 ± 2.20^{c}	12.22 ± 2.99^{c}	18.77 ± 3.82^{c}	22.66 ±3.25^{d}	-
	P*W	-	1.38 ± 0.25^{cd}	4.65 ± 0.81^{a}	6.92 ±1.31^{b}	9.29±2.01^{b}	12.42 ± 3.13^{b}	14.04 ± 2.88^{b}	15.26 ±3.19^{a}
	C*W	-	1.30 ± 0.59^{d}	6.35 ± 0.83^{c}	9.65 ± 1.19^{c}	13.48 ± 2.25^{c}	20.27 ±1.84^{c}	25.55 ±2.56^{e}	-
pH	Control	4.42 ±0.01^{a}	4.63 ± 0.02^{c}	4.67 ± 0.02^{c}	4.86 ± 0.02^{f}	-	-	-	-
	Wax	4.51±0.07^{c}	4.51 ± 0.01^{b}	4.57 ± 0.01^{b}	4.72±0.01^{d}	4.74±0.01^{b}	4.79 ± 0.01^{b}	5.70 ± 0.03^{c}	-
	Chitosan	4.41 ± 0.05^{a}	4.46±0.03^{a}	4.52±0.02^{a}	4.80 ± 0.01^{e}	4.80 ± 0.04^{e}	4.84 ± 0.01^{c}	-	-
	Pectin	4.41 ±0.01^{a}	4.47±0.01^{a}	4.55 ± 0.01^{a}	4.55 ± 0.01^{a}	4.70 ± 0.01^{a}	4.75 ± 0.02^{a}	5.67 ±0.01^{c}	-
	P*C	4.51 ± 0.01^{c}	4.55 ±0.01^{b}	4.57 ± 0.01^{b}	4.58 ± 0.02^{b}	4.79 ± 0.04^{d}	4.86 ± 0.02^{d}	5.03 ± 0.03^{a}	-
	P*W	4.43 ± 0.06^{b}	4.47 ±0.02^{a}	4.53 ± 0.02^{a}	4.70 ± 0.01^{c}	4.80 ± 0.01^{e}	4.87 ± 0.02^{d}	5.79 ± 0.02^{d}	5.87 ± 0.02^{a}
	C*W	4.53 ± 0.00^{d}	4.55 ±0.02^{b}	4.62 ± 0.02^{c}	4.72 ±0.03^{d}	4.76 ± 0.02^{c}	4.82 ± 0.03^{c}	5.09 ± 0.11^{b}	-
TSS (°Bx)	Control	4.49 ± 0.02^{c}	5.23±0.51^{de}	5.54 ± 0.02^{e}	5.72 ±0.29^{e}	-	-	-	-
	Wax	3.98 ± 0.28^{a}	4.24 ±0.11^{a}	4.37 ± 0.12^{b}	4.45± 0.02^{a}	4.93 ± 0.59^{a}	4.97 ± 0.58^{a}	5.03 ± 0.58^{a}	-
	Chitosan	5.48 ± 0.08^{e}	5.28 ± 0.35^{d}	5.16 ± 0.27^{c}	5.53 ± 0.05^{c}	5.56 ± 0.05^{b}	5.58 ± 0.05^{b}	-	-
	Pectin	4.45 ± 0.30^{b}	5.04 ±0.176^{c}	5.23 ±0.06^{d}	5.34 ±0.03^{b}	5.61 ± 0.39^{bc}	5.69 ± 0.45^{ab}	5.81 ± 0.61^{c}	-
	P*C	5.56 ± 0.01^{f}	4.76 ± 0.01^{b}	3.66 ± 0.01^{a}	5.64 ± 0.05^{d}	5.64 ± 0.05^{c}	5.65 ± 0.04^{ab}	5.69 ± 0.06^{b}	-
	P*W	5.27 ± 0.03^{d}	4.67 ± 0.27^{b}	6.31 ±0.11^{f}	6.39 ± 0.07^{f}	6.36 ± 0.05^{e}	6.46 ± 0.05^{d}	6.53 ± 0.01^{e}	6.56 ± 0.02^{a}
	C*W	5.51 ± 0.03^{e}	5.37 ± 0.22^{e}	5.55 ± 0.01^{e}	5.74 ±0.01^{e}	5.93 ± 0.02^{d}	6.07 ± 0.07^{c}	6.21 ± 0.09^{d}	-

**The data were statistically analysed using Duncan's multiple range test (DMRT). Data represent the mean± standard deviation (SD) of the experiments. Values followed by different letters within the same column, are significantly different at P < 0.05 level are indicated by different letters.*

*Trt=treatment, p*c=pectin with chitosan, p*w= pectin with beeswax, cw= chitosan with beeswax, WL= Weight loss (%), TSS=Total soluble solids (brix)*

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4.1.2 pH

In the present study table 5, edible film coating has shown that there is a significantly slow rate of increase in pH value, whereas in case of uncoated tomatoes the rate of increment of pH was high and the degradation of acid was high. These finding agrees with the fruit's pH always rising during maturation due to the consumption organic acid for the metabolic processes during respiration (Wu *et al*., 2016; Tumwesigye, *et al*., 2017). This is also supported by Firdous *et al*. (2020), who reported that edible coating solutions containing 80% aloe vera gel with 2% calcium chloride treatment has slightly increased the pH value from 4.98 to 5 after 30 days storage period, which shows that biochemical reactions leading towards ripening and decay were slowed down by aloe vera gel-based coating, the finding was in agreement with this statement. In contrast, a study reported that the pH value of was decrease from 4.75 to 3.65 after 15 and 18 days of storage, respectively, at room temperature (Kumar *et al*., 2021).

In our study, the pH value of different edible coating materials have significant difference, tomatoes coated with chitosan & wax (1:1) has showed that the high pH record and the rate of increment along the storage day was high in uncoated tomato. The pH value of tomatoes coated with edible film coating materials was increased from 4.53 to 5.87 in 35 days of storage time. Where as in the case of uncoated tomatoes the pH rises from 4.42 to 4.86 within day 15 storage time. The available information has indicated that different types of edible coating used have shown variation in their influence on the pH of tomato fruits. The possible reason for this might be the difference in nature of edible coating used, and the stage of maturity of tomato and tomato variety.

4.1.3 Total Soluble Solids (Brix)

In the current study, the Total soluble solids in tomatoes increased with storage period and the maximum value was recorded for uncoated tomato fruits as compared with other treatments, this could be due to the slower decrease in acidity in the coated fruits resulting in a slower ripening process (Ullah *et al*., 2017). The increase in TSS may be due to the complete hydrolysis of starch into simple sugars up to 35 days of storage (table 5). The TSS content of tomatoes shows significant differences until the 15th day of storage. After day 15, there is a consistent increase with no significant variation. This is in agreement with, Chrysargyris *et al*. (2016), who reported that 10% and 15% aloe gel-coated tomatoes have shown significant differences in TSS until the 7th day of storage. However, after the 7th day, both coated and uncoated tomatoes shown no any differences in TSS. It has been reported that TSS increases with the stage of ripeness at harvest (Znidarcic and Pozrl, 2006) and also it generally increases with advancement in maturity during storage (Getinet *et al*., 2008) which is in agreement with the current result. In terms of total soluble solids (TSS), the results indicated a

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consistent increase from day 0 to day 35 for tomatoes coated with a mixture of pectin and wax (1:1). For those coated with wax, pectin, and a blend of wax and chitosan (1:1), the increase was observed from day 0 to day 30. Chitosan-coated tomatoes showed an increase from day 0 to day 25, while uncoated tomatoes demonstrated an increase from day 0 to day 15. The combination of wax and pectin resulted in the highest TSS value recorded at 6.56, measured on day 35. This was statistically different from the other treatments. Total soluble solids represent the amount of sugar and soluble minerals present in fruits and vegetables. Overall, the study found that TSS increased consistently from day 0 to day 35 across tomatoes treated with various coating materials as well as in uncoated tomatoes. With regards to the total soluble solids, the results showed that, there was a consistency increment of TSS from day 0 to day 35 in case of pectin and wax (1:1) coated tomato, 0 to day 30 in wax, pectin, blend of wax and chitosan (1:1), 0 to 25 day in chitosan coated tomatoes and 0 to 15 day in uncoated tomatoes.

The wax combination with pectin coated fruit had maximum TSS (6.56) was recorded at 35 day, which was statistically different from the TSS which are the amount of sugar and soluble minerals present in fruits and vegetables. From the study, it was seen that there were consistencies in increasing the TSS from day 0 to day 35 days along with tomatoes treated with different coated materials and uncoated tomato. This may be due to some chemical reactions and changes over the storage period and also changes in the starch concentration during the postharvest period (Kays, 1997). Coatings provide an excellent semi-permeable film around the fruit, modifying the internal atmosphere by reducing O2 availability for respiration and degradation of macromolecules. Decreased respiration rates slow down the synthesis and use of metabolites resulting in a slower rate of increase in TSS (Yaman and Bayoindirli, 2002).

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Table 6: Acidity, titratable acidity and acid ratio of coated and uncoated tomato samples analysis.

Parameter	Trt.	Storage day							
		0	5	10	15	20	25	30	35
Acidity (%)	Control	6.67 ± 0.04^{c}	5.60 ± 0.01^{c}	5.23 ± 0.02^{b}	4.73 ± 0.04^{b}	-	-	-	-
	Wax	5.37 ± 0.13^{a}	5.25 ± 0.01^{a}	4.87 ± 0.06^{a}	4.87 ± 0.06^{c}	4.37 ± 0.04^{b}	4.29 ± 0.08^{c}	4.17 ± 0.06^{b}	-
	Chitosan	7.06 ± 0.16^{d}	5.60 ± 0.02^{c}	4.72 ± 0.02^{a}	4.59 ± 0.04^{a}	4.56 ± 0.06^{c}	3.87 ±0.06^{b}	-	-
	Pectin	7.03 ± 0.15^{d}	6.64 ± 0.06^{f}	5.27 ± 0.02^{bc}	4.61 ± 0.09^{a}	3.58 ± 0.07^{a}	2.83 ± 0.03^{a}	2.72 ± 0.06^{a}	-
	P*C	7.23±0.12^{e}	6.30 ± 0.10^{e}	6.08 ± 0.08^{e}	5.26 ±0.14^{d}	4.71 ± 0.02^{d}	4.63 ± 0.02^{e}	4.59 ± 0.01^{d}	-
	P*W	5.93±0.02^{b}	5.91±0.04^{d}	5.61±0.02^{d}	5.36 ± 0.15^{e}	5.24 ± 0.08^{e}	4.55±0.06^{d}	4.23 ± 0.17^{bc}	3.57 ± 0.64^{a}
	C*W	5.80 ± 0.14^{b}	5.43 ± 0.09^{b}	5.20 ± 0.07^{b}	4.86 ± 0.06^{c}	4.84 ± 0.07^{d}	4.60 ± 0.06^{d}	4.19 ± 0.11^{b}	-
Titratable acidity(%)	Control	0.44 ± 0.04^{b}	0.38 ± 0.03^{a}	0.38 ± 0.01^{a}	0.38 ± 0.01^{a}	-	-	-	-
	Wax	0.39 ± 0.02^{a}	0.38 ± 0.03^{a}	0.36 ±0.03^{b}	0.38 ± 0.03^{a}	0.34 ±0.03^{a}	0.33 ±0.03^{a}	0.319±0.03^{a}	-
	Chitosan	0.43 ± 0.01^{b}	0.41 ±0.01^{b}	0.38±0.01^{a}	0.36 ±0.01^{a}	0.57±0.02^{e}	0.47±0.01^{cd}		-
	Pectin	0.62 ± 0.01^{d}	0.58±0.01^{d}	0.56 ±0.01^{d}	0.53 ± 0.01^{d}	0.49 ± 0.01^{c}	0.48 ±0.01^{de}	0.45 ± 0.03^{bc}	-
	P*C	0.57± 0.01^{c}	0.56 ±0.01^{c}	0.54 ±0.01^{c}	0.44±0.06^{b}	0.46 ± 0.01^{b}	0.44 ± 0.01^{b}	0.43 ± 0.01^{b}	-
	P*W	0.62 ± 0.02^{d}	0.59 ± 0.01^{d}	0.57 ±0.01^{d}	0.55±0.01^{d}	0.48 ± 0.01^{c}	0.46 ± 0.01^{c}	0.45 ±.01^{bc}	0.44 ±0.02^{a}
	C*W	0.57 ± 0.01^{c}	0.56 ± 0.01^{c}	0.53 ± 0.02^{c}	0.51 ±0.01^{bc}	0.52 ± 0.01^{d}	0.47 ± 0.01^{cd}	0.44 ± 0.02^{b}	-
Acid ratio	Control	0.67 ± 0.01^{b}	0.93 ± 0.09^{d}	1.06 ± 0.01^{c}	1.21±0.05^{c}	-	-	-	-
	Wax	0.74 ± 0.04^{c}	0.81± 0.02^{c}	0.89 ± 0.03^{b}	0.92 ±0.01^{a}	1.13 ± 0.14^{a}	1.16 ± 0.12^{a}	1.21 ± 0.13^{a}	-
	Chitosan	0.78 ± 0.02^{c}	0.94 ±0.06^{d}	1.09 ± 0.06^{c}	1.21 ±0.01^{c}	1.22 ± 0.02^{c}	1.44 ± 0.03^{dc}	-	-
	Pectin	0.63 ± 0.03^{a}	0.76 ± 0.03^{a}	0.99 ± 0.02^{b}	1.16 ±0.03^{b}	1.56 ± 0.11^{d}	2.01 ± 0.16^{e}	2.14 ±0.19^{d}	-
	P*C	0.77± 0.02^{c}	0.75 ± 0.01^{a}	0.61 ± 0.01^{a}	1.07 ±0.04^{b}	1.19 ± 0.02^{b}	1.22 ± 0.01^{b}	1.24 ± 0.02^{a}	-
	P*W	0.88 ± 0.01^{d}	0.79 ±0.04^{b}	1.12± 0.02^{d}	1.19 ± 0.05^{bc}	1.22 ± 0.01^{c}	1.42 ± 0.02^{c}	1.54 ± 0.06^{c}	1.87 ± 0.30^{a}
	C*W	0.95 ± 0.02^{e}	0.99 ± 0.04^{e}	1.07 ± 0.02^{c}	1.18 ± 0.02^{bc}	1.23 ± 0.02^{c}	1.32 ± 0.03^{c}	1.48 ± 0.02^{b}	-

**The data were statistically analysed using Duncan's multiple range test (DMRT). Data represent the mean± standard deviation (SD) of the experiments. Values followed by different letters within the same column, are significantly different at P < 0.05 level are indicated by different letters. Trt=treatment, p*c=pectin with chitosan, p*w= pectin with beeswax, cw= chitosan with beeswax*

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4.1.4 Acidity

The acidity of tomato is one of the important quality parameters that plays a major role and imparts the taste of the fruits. The acidity of tomatoes decreases with ripening. Tomatoes are very sensitive to respiration activity after harvest because citric acid is metabolized in order to supply intermediates to the tri carboxylic acid cycle during increases in respiration (Khatri *et al*., 2020; Sree *et al*., 2020). The alterations in levels of organic acids during ripening are due to increase in citrate and decrease in the level of maltase suggesting a variation in metabolism of citrate and reduction in the level of citric acid (Kumar *et al*., 2020). Edible coatings reduce the respiration rate and maintain the activity of organic acids during storage (Lietal., 2017).

The table 6 illustrated that the rate of acidity reduction was slower for tomatoes coated with various edible film materials compared to uncoated tomatoes. The acidity of tomatoes significantly decreased over different storage periods: from day 0 to day 35 for pectin and wax-coated tomatoes, from day 0 to day 30 for tomatoes coated with wax, pectin, wax, and chitosan, and from day 0 to day 25 for chitosan-coated tomatoes. This indicates that the acid content decreased over the storage days, while the coated materials helped to slow down the rate of acid degradation. Notably, the findings reveal that the combination of wax and pectin (1:1) coated tomatoes retained the maximum level of acidity (3.57) after 35 days of storage.

4.1.5 Titratable acidity

The titratable acidity of the tomatoes decreased as they matured and with each day of storage. The results from the above table indicate that the titratable acidity decreased from the initial storage day to 35 days across various samples treated with edible film coatings, as well as in the control group. The same results were observed in a study by Raffo *et al*., (2002) which shows the acidity decreased with maturation. In general, the decrease in acidity over time seems more pronounced in uncoated tomatoes compared with coated tomatoes and may be related to high ethylene production and respiration rate during ripening (Das *et al*., 2013; Oz and Ulukanli, 2011).

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4.1.6 Acid ratio

The titratable acidity (TA) of tomatoes was significantly influenced by both the storage duration and the type of coating materials used. The data indicated that the acidity of tomatoes, whether treated with various coating materials or left uncoated, consistently decreased from the initial storage days until the maximum storage period. This continuous reduction in acidity was observed throughout the study. Specifically, tomato samples coated with a combination of pectin and wax (1:1) recorded the highest acidity value of 1.82 at 35 days of storage. Our findings align with those of Nirupama *et al.* (2010), who noted that changes in titratable acidity during storage are primarily due to the metabolic activities of the living tissues in the tomato, leading to the depletion of organic acids. Hatami *et al*. (2013) also emphasized that the decline in TA may be associated with increased ripening and respiration rates, where organic acids are utilized as a substrate during respiration or are converted into other sugars. They reported a significant reduction in TA for tomatoes stored at 25°C compared to those stored at 13°C and 5°C. This observation is supported by Abiso *et al*. (2015), who found that higher storage temperatures and advanced ripening stages resulted in greater TA reductions. Similar results were reported by Munhuewyi, (2012) for tomatoes stored at 22°C for seven days.

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Table **7:** Total sugar, reducing sugar, and non-reducing sugar coated and uncoated tomato analysis.

Parameter	Trt.	**Storage day**							
		Day 0	Day 5	Day 10	Day 15	Day 20	Day 25	Day 30	Day 35
Total sugar (%)	Control	4.11 ± 0.11^{a}	4.49 ± 0.06^{a}	5.04 ± 0.03^{a}	5.42 ± 0.05^{a}	--	-	-	-
	Wax	4.33 ±0.06^{c}	4.62 ±0.04^{b}	5.06 ± 0.04^{a}	5.52 ±0.06^{b}	5.40 ± 0.32^{a}	6.26 ± 0.02^{bc}	6.50 ± 0.06^{bc}	-
	Chitosan	4.46 ± 0.08^{d}	4.74 ± 0.09^{c}	5.18 ± 0.01^{b}	5.61 ±0.03^{b}	6.05 ± 0.02^{c}	6.34 ±0.05^{c}	-	-
	Pectin	4.38 ± 0.05^{c}	4.75 ± 0.03^{c}	5.18 ± 0.07^{b}	5.61 ± 0.06^{b}	5.95 ± 0.09^{b}	6.31± 0.06^{c}	6.59 ±0.06^{c}	-
	P*C	4.60±0.05^{f}	4.77 ±0.03^{cd}	5.20±0.09^{bc}	5.53 ± 0.12^{b}	5.98 ± 0.19^{b}	6.27 ± 0.11^{bc}	6.51 ± 0.13^{b}	-
	P*W	4.25±0.04^{b}	4.60 ±0.11^{b}	5.01 ±0.10^{a}	5.42 ±0.06^{a}	5.69 ± 0.01^{a}	6.14 ±0.06^{a}	6.38 ± 0.06^{a}	6.6±0.00^{a}
	C*W	4.53±0.06^{d}	4.84 ± 0.03^{d}	5.32 ±0.04^{a}	5.66 ±0.05^{c}	6.09 ±0.05^{c}	6.27 ± 0.05^{b}	6.54 ± 0.06^{b}	-
Reducing sugar(%)	Control	2.99±0.02^{a}	3.19 ± 0.05^{a}	3.53 ± 0.05^{b}	3.72 ± 0.01^{a}	-	-	-	-
	Wax	3.12±0.05^{c}	3.26 ± 0.04^{b}	3.56 ±0.06^{b}	3.79 ± 0.04^{b}	3.58 ± 0.29^{a}	4.39 ± 0.04^{b}	4.58 ± 0.06^{b}	-
	Chitosan	3.18±0.08^{c}	3.37±0.09^{c}	3.64±0.02^{bc}	3.86 ± 0.04^{c}	4.23 ±0.01^{d}	4.46 ± 0.04^{c}	-	-
	Pectin	3.18±0.07^{c}	3.36 ±0.02^{c}	3.61 ±0.03^{bc}	3.84 ±0.02^{c}	4.09 ± 0.07^{c}	4.42 ± 0.09^{c}	4.65 ±0.08^{c}	--
	P*C	3.33±0.05^{d}	3.44 ±0.02^{c}	3.66±0.03^{c}	3.82 ±0.01^{c}	4.22 ±0.10^{e}	4.44 ±0.07^{c}	4.63 ±0.11^{bc}	-
	P*W	3.04±0.05^{b}	3.27 ±0.06^{b}	3.52 ± 0.01^{b}	3.76 ±0.03^{b}	3.94 ±0.02^{b}	4.31 ±0.06^{a}	4.5 ±0.05^{a}	4.71 ±0.02^{a}
	C*W	3.24±0.04^{c}	3.43±0.02^{c}	3.70 ±0.02^{d}	3.84 ±0.04^{c}	4.23 ±0.02^{e}	4.39 ± 0.04^{b}	4.62 ±0.04^{bc}	-
Non-Reducing sugar(%)	Control	1.12±0.10^{a}	1.31±0.01^{a}	1.51 ± 0.02^{ab}	1.69 ± 0.06^{a}	-	-	-	-
	Wax	1.23±0.03^{b}	1.35±0.01^{b}	1.50 ± 0.01^{a}	1.73 ± 0.07^{ab}	1.82 ± 0.03^{b}	1.87 ± 0.02^{a}	1.92±0.01^{b}	-
	Chitosan	1.28±0.01^{c}	1.36±0.01^{b}	1.54±0.03^{b}	1.74 ±0.00^{ab}	1.83 ± 0.01^{b}	1.88 ± 0.01^{ab}	-	-
	Pectin	1.20±0.07^{b}	1.39±0.01^{c}	1.58 ±0.05^{d}	1.76±0.05^{ab}	1.86 ±0.03^{c}	1.89 ± 0.04^{ab}	1.94 ±0.02^{c}	-
	P*C	1.28±0.01^{c}	1.34±0.05^{a}	1.53 ±0.12^{b}	1.71±0.12^{a}	1.77±0.10^{ab}	1.84 ±0.05^{a}	1.88 ±0.05^{b}	-
	P*W	1.21±0.02^{b}	1.32±0.04^{ab}	1.49±0.05^{a}	1.76 ± 0.05^{a}	1.76 ±0.02^{a}	1.82 ± 0.02^{a}	1.86 ±0.01^{a}	1.89 ± 0.02^{a}
	C*W	1.28±0.03^{c}	1.41±0.02^{d}	1.61±0.03^{c}	1.82 ± 0.04^{ab}	1.86 ±0.03^{c}	1.88 ± 0.01^{b}	1.92 ±0.02^{b}	-

**The data were statistically analysed using Duncan's multiple range test (DMRT). Data represent the mean± standard deviation (SD) of the experiments. Values followed by different letters within the same column, are significantly different at P < 0.05 level are indicated by different letters. Trt=treatment, p*c=pectin with chitosan, p*w= pectin with beeswax, cw= chitosan with beeswax.*

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4.1.7 Total sugar

The total sugar content of tomatoes treated with different coating materials, as well as uncoated tomatoes, showed significant differences over the storage period. The total sugar percentage of the tomatoes was influenced by various treatments, including chitosan, pectin, wax, and combinations of these materials (pectin with wax, pectin with chitosan, and wax with chitosan). Notably, significant variations in total sugar content were observed from days 5 to 35 across the different coatings. The total sugar levels in the tomatoes increased over time, reaching their peak at 35 days for those coated with a blend of pectin and wax, and at 30 days for those treated with chitosan and wax, as well as for those with only wax or pectin coatings. In contrast, uncoated tomatoes only showed an increase in total sugar content up to 15 days of storage. Among all the treatments, the tomatoes coated with pectin and wax exhibited the highest total sugar content, measuring at 6.6%, followed closely by pectin alone at 6.59%, and wax at 6.5%. This increase in sugar levels may be attributed to the rapid conversion of polysaccharides into sugars.

4.1.8 Reducing sugar

Reducing sugar content of tomato changes during the storage is presented in table 7. The two way interaction between the coating material and storage day were significant as depicted in table 7. The finding indicates that the effect of the changes in the reducing sugar content was increase from 5-35 storage days along different coating materials. The increase in reducing sugar content could be due to the breakdown of poly saccharides into water-soluble sugar (Žnidarcic and Pozrl, 2006). Higher value in reducing sugar (4.71) was found in pectin and wax coated tomatoes at 35 days of storage time.

4.1.9 Non-Reducing sugar

The non-reducing sugar content (%) of tomatoes varied based on different of coating material treatments solutions. The highest level of non-reducing sugar was observed in tomatoes coated with a pectin and wax mixture (1:1) after 35 days of storage. In contrast, uncoated tomatoes exhibited the lowest non-reducing sugar level at 1.69% after 15 days of storage. It is important to note that the amount of non-reducing sugar (sucrose) in tomatoes is significantly lower compared to reducing sugars (such as fructose and glucose).

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Table 8: Effect of storage days on lycopene and vitamin C content in coated and uncoated tomato sample at Ambient Conditions.

Treatment	Storage day			
	Lycopene		Vitamin C	
	Initial (day 0)	Final (storage termination date)	Initial (day 0)	Final (storage termination date)
Control	14.08±0.43^{d}	18.30±0.15^{e}	48.02±0.08^{c}	43.61±0.02^{c}
Wax	3.50±0.35^{a}	16.66±1.05^{c}	44.45±0.36^{d}	42.07±0.08^{b}
Chitosan	15.77±0.08^{e}	17.53±0.28^{d}	43.18±0.09^{c}	42.69±0.03^{b}
Pectin	7.75±0.57^{b}	11.16±0.16^{a}	42.15±0.02^{b}	41.55±0.04^{a}
P*C	17.47±0.64^{f}	24.41±0.56^{g}	41.39±0.01^{a}	40.78±0.05^{a}
P*W	14.83±0.93^{d}	20.58±0.23^{f}	43.27±0.15^{e}	43.11±0.011^{b}
C*W	11.69±0.24^{c}	14.90±0.30^{b}	44.30±0.05^{d}	43.7267±0.23^{c}

**The data were statistically analysed using Duncan's multiple range test (DMRT). Data represent the mean± standard deviation (SD) of the experiments. Values followed by different letters within the same column, are significantly different at P < 0.05 level are indicated by different letters. P*c=pectin with chitosan, p*w= pectin with beeswax, c*w= chitosan with beeswax.*

4.1.10 Lycopene Content

Lycopene is the most abundant carotenoid compound in tomatoes, giving the fruit its distinctive red color (Frusciante *et al*., 2007). Ripening causes a drop in chlorophyll content and a rapid production of the red pigment lycopene. Table 8 illustrates the variations in the lycopene content of tomato fruits under different coating materials control, beeswax, chitosan, pectin, pectin with chitosan, pectin with beeswax, and chitosan with beeswax on the initial and final days of storage at ambient temperature. The current study found a substantial ($P < 0.05$) change in the lycopene concentration of tomato fruits due to the interaction impact of edible covering materials. Overall, the lycopene concentration of tomato fruits rose with storage time in both coated and uncoated fruits (Table 8), which was associated with ripening phases. However, the content of uncoated fruits climbed dramatically and reached a peak during the final days of storage. On the first day of storage, however, lycopene concentrations were comparable between control and pectin with beeswax coated fruits. The ripening and antioxidant index of tomatoes (lycopene) varies from one ripening stage to the next, and these variations were found with both coated and uncoated fruits. The lowest lycopene concentration (3.50 mg/100 g) was recorded in wax coated fruits at the initial stage after the final days of storage while the highest concentration of 20.58 mg/100 g for pectin with beeswax coated fruits which were at the final stage on the 35th day after coating and of storage.

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The early increase in lycopene content in control fruits might be due to the faster ripening rate of fruits which leads to the conversion of chloroplasts to chromoplasts and lycopene accumulation in internal membrane system (Grierson and Kader, 1986). The study's findings are similarly consistent with those of Ali *et al*. (2013), who found that while tomatoes coated with gum arabic remained high for 16 days, the lycopene content of uncoated tomatoes rose significantly and peaked after 12 days of storage. Additionally, it has been noted that the rate of respiration during storage affects the production of lycopene (Javanmardi and Kubota, 2006). As previously mentioned, coatings lower fruit respiration rates by reducing the amount of oxygen available.

4.1.11 Vitamin C content

The majority of fruits and vegetables naturally contain enough amounts of vitamin C, which has antioxidant properties. Sharma et al. (1996) reported variation in ascorbic acid content ranging from 11.21 to 53.29 mg·100g-1 in tomato genotypes. The vitamin C concentration of tomatoes is significantly influenced by the variety, maturity stage, and environmental factors. Over the course of the storage period, the vitamin C content of both coated and untreated tomatoes dropped (table 8). Uncoated samples showed a slow decline. Compared to uncoated tomatoes, coated tomatoes preserved greater vitamin C at the end of the storage period. This could be because various coating materials, such as beeswax, chitosan, and pectin, functioned as gas barriers, preventing oxygen from penetrating the fruit and lowering vitamin C oxidation. Therefore, by removing oxygen from the packaging headspace and adding antioxidants to films and coatings to improve the antioxidant qualities of food surfaces, oxidation of food items can be avoided (Sahraee *et al*., 2019). However, ascorbic acid oxidase and phenol oxidase activities caused it to be lost at a later stage of storage (Ghosh *et al.,* 2015).

According to Tigist *et al*. (2013), vitamin C is one of the most significant nutritional value parameters in fruits and vegetables. Additionally, the data indicate that they are generally significantly different from ($p<0.05$). High levels of acidity are known to be the cause of vitamin C's stability during storage. Additionally, because of its protective properties, phenolic compounds have also been connected to the stability of vitamin C (Ajayi and Oderinde, 2013). The findings align with those of prior research (Dumas *et al.,* 2003; Toor and Savage, 2006). Lastly, as table 8 illustrates, it was also noted that the vitamin C concentration decreased gradually on the final day of storage. The results of this study are supported by treatments that include natural preservatives like pectin, chitosan and wax, which have been demonstrated to improve nutrient retention in a variety of food products. This implies that combining these treatments could be a practical way to enhance the nutritional value of goods that are kept in storage.

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4.1.12 proximate Analysis

Table 9: Proximate composition of tomato coated and uncoated with different coating materials.

Treatment		Proximate composition					
		Moisture (%)	Protein (g/100g)	Fat (g/100g)	Ash (g/100g)	Crude Fiber (g/100g)	Carbohydrate K/Cal
Control	Initial	94.97 ± 0.13^{a}	0.93 ±0.02^{a}	0.24 ± 0.05 ^{a}	0.66 ± 0. 01 ^{a}	1.26 ± 0.03^{a}	2.27 ± 0.07^{a}
	Final	94.68 ± 0.18^{b}	0.83 ± 0.03^{b}	0.21 ± 0.01 ^{a}	0.61 ± 0.02 ^{a}	1.20 ± 0.04^{b}	2.14 ± 0.08^{a}
Pectin	Initial	94.47 ± 0.42 ^{a}	1.07 ± 0.07^{a}	0.24 ± 0.02 ^{a}	0.73 ± 0.05^{a}	1.46 ± 0.1^{a}	2.65 ± 0.18^{a}
	Final	93.83 ± 0.14^{b}	0.96 ± 0.2^{b}	0.21 ± 0.01^{a}	0.65 ± 0.02^{a}	1.34 ± 0.03^{b}	2.33 ± 0.06^{a}
Beeswax	Initial	94.49 ± 0.16^{a}	0.96 ± 0.03^{a}	0.29 ± 0.01^{a}	0.73 ± 0.02^{a}	1.46 ± 0.04^{a}	2.65 ± 0.07^{a}
	Final	93.87 ± 0.12^{b}	1.28 ± 0.02^{b}	0.22 ± 0.01^{a}	0.65 ± 0.01^{a}	1.31 ± 0.03^{b}	2.32 ± 0.05^{b}
Chitosan	Initial	93.75 ± 0.44^{a}	1.07 ± 0.08^{a}	0.24 ± 0.02^{a}	0.87 ± 0.05^{a}	1.75 ± 0.1a	3.15 ± 0.19^{a}
	Final	92.63 ± 0.52^{b}	1.09 ±0.08^{b}	0.21 ± 0.02^{a}	0.74 ± 0.06^{b}	1.48 ± 0.12^{b}	2.67 ± 0.22^{b}
Pectin*beeswax	Initial	94.09 ± 0.32^{a}	1.15 ± 0.06^{a}	0.26 ± 0.01 ^{a}	0.79 ± 0.04^{a}	1.41 ± 0.08^{a}	2.52± 0.14 ^{a}
	Final	93.42 ± 0.22^{b}	1.03 ± 0.04^{b}	0.23 ± 0.01 ^{a}	0.75± 0.03^{a}	1.16 ± 0.05 ^{b}	2.31 ±0.09^{b}
Pectin*chitosan	Initial	94.63 ± 0.37^{a}	1.08 ± 0.06 ^{a}	0.24 ± 0.01 ^{a}	0.70 ± 0.04 ^{a}	1.47 ± 0.09^{a}	2.64 ± 0.16^{a}
	Final	93.82 ± 0.34^{b}	0.93 ± 0.06 ^{a}	0.21 ± 0.01 ^{a}	0.64 ± 0.04 ^{a}	1.28 ± 0.08^{b}	2.29 ± 0.15^{b}
Chitosan*beeswax	Initial	94.35 ± 0.15^{a}	1.14 ± 0.03 ^{a}	0.26 ± 0.01 ^{a}	0.78 ± 0.02^{a}	1.56 ± 0.04^{a}	2.81 ± 0.07 ^{a}
	Final	93.43 ± 0.48^{b}	0.98 ± 0.08 ^{b}	0.22± 0.02^{b}	0.67± 0.06^{b}	1.34 ± 0.11^{b}	2.41 ± 0.21^{b}

Data are an average (mean ± SD). Different letters in each column indicate that the values differ significantly at α = 0.05, Initial and final date indicate day 0 and storage termination date respectively.

The moisture contents of tomato(Galilea hybrid) were ranged from 93.42 to 94.97% and 73.40, Protein (0.96% to 1.14%), Fat (0.21% to 0.29%), Ash (0.61 % to 0.87 %), Crude fiber (1.16 % to 1.75%) and Carbohydrate content (2.14 % to 3.15%) respectively.

This study reveals that the impact of various edible coatings (pectin, beeswax, chitosan, and their combinations) on the proximate composition of tomatoes during storage, compared to an uncoated control. A primary indicator of coating efficacy, moisture content, revealed significant reductions ($p<0.05$, based on differing superscripts) from initial to final storage for all groups, including the control. In theory, a decrease in moisture should concentrate the solid components, resulting in a rise in their percentage of the fresh weight. However, the control group saw large declines in protein and fiber. While moisture fell dramatically in pectin-coated tomatoes, protein and fat remained unchanged, while fiber decreased significantly. This overall departure from the expected concentration response across multiple treatments suggests that simple dehydration was not the only factor influencing the final proximate composition.

When examining certain treatments, the protein content increased greatly with beeswax coating, which was partly consistent with the concentration effect. At the same time, the content of fiber and carbohydrates dramatically decreased, while the content of fat and ash did not change significantly. Even though they lost a lot of moisture, tomatoes coated with chitosan showed a notable gain in protein but a considerable drop in ash, fiber, and carbohydrates, while the amount of fat remained

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constant. The majority of the dry matter components in the combination coatings (Pectin*Beeswax, Pectin*Chitosan, and Chitosan*Beeswax) showed significant decreases or no significant changes, with the exception of Pectin*Beeswax, which showed a non-significant change in protein. All other coatings showed significant decreases or stability instead of the expected increases that come with water loss.

The change in Protein, fat, ash, fiber, and carbohydrate levels frequently follow an expected pattern as a result of dehydration, with many components falling dramatically or remaining unchanged. The significant increase in protein for beeswax and chitosan treatments is noteworthy, but the concurrent decrease in other solids in most groups suggests that metabolic processes (such as respiration consuming carbohydrates and possibly other components) or the specific nature of the tomato-coating interaction may play a more complex role than simple moisture barrier effects. These findings indicate the importance of taking into account metabolic processes and coating interactions when assessing the overall impact on tomato quality.

4.1.13 Disease incidence

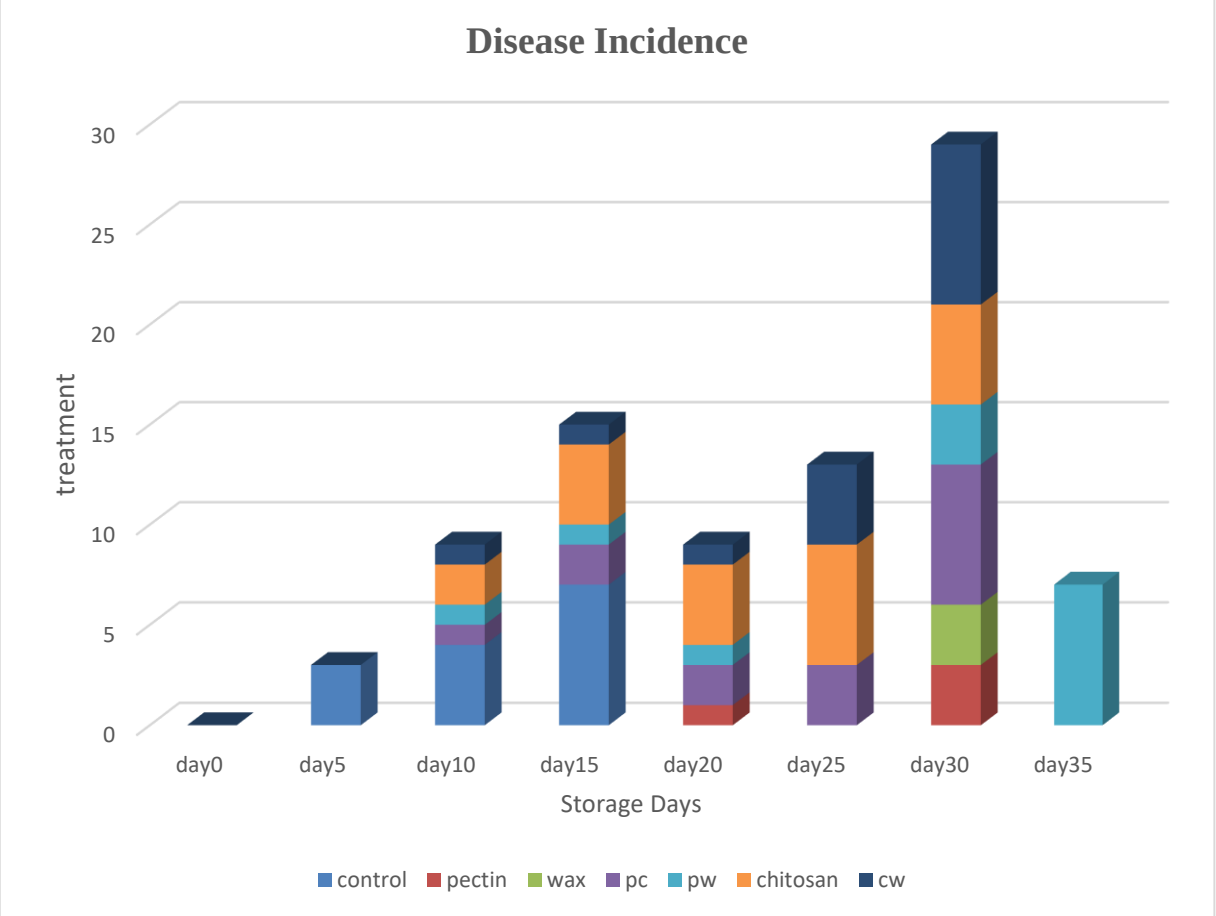

Figure 8. Effect of coating materials during storage on disease incidence of coated and uncoated tomato fruit.

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Results in Figure 8 indicate that the incidence of diseases was significantly ($P<0.05$) affected by the interaction effect of coating and storage days. The data presented in the graph illustrates the incidence of disease in tomatoes stored over different days with various coating treatments. The uncoated tomatoes showed a significant increase in disease incidence from day 5 to day 15, indicating that the lack of protective treatment leads to higher microbial activity. The uncoated tomatoes (control) exhibited the highest disease incidence by the end of the 15-day storage period, at which point the storage was terminated. This is in agreement with the studies (Abebe *et al*., 2017), which is the incidence was significantly lower on coated tomato fruits as compared with uncoated ones. The tomatoes coated with pectin initially demonstrated some control over disease incidence; however, this protection diminished over time, resulting in increased microbial growth and disease development as storage continued. In contrast, the wax-coated tomatoes provided consistent protection, keeping disease incidence at lower levels throughout the storage period. This suggests that wax coatings have effective barrier properties against microbial infiltration. Chitosan-coated tomatoes offered moderate control, showing noticeable increases in disease incidence during the later stages, which indicates limited long-term efficacy.

The incidence was significantly lower on coated tomato fruits than uncoated ones. On the other hand, after the 15th day of storage at ambient conditions the disease incidence on fruits of control were spoiled, where as in most coated tomato start to contaminate at day 10th chitosan, pectin with chitosan, pectin with beeswax and chitosan with beeswax coated fruits. Abbasi et al. (2009) also observed the decay control of irradiated beeswax coated tomato fruit as compared to uncoated ones. Many of the control fruits (67%) were spoiled after 15 days of storage (Ali *et al*., 2010). Tomatoes with combined coatings, specifically P*w (pectin + wax), provided better protection than those coated with pectin alone, as they exhibited reduced disease incidence over time. The P*c combination (pectin + chitosan) demonstrated intermediate control, balancing the effectiveness between the individual pectin and chitosan coatings. Meanwhile, the C*w combination (chitosan + wax) proved to be the most effective, maintaining the lowest levels of disease incidence, especially during extended storage periods.

Furthermore, the coating can reduce rate of respiration and ethylene synthesis. These conditions in combination could assist cell wall to retain more integrity against fungal attack (Hassan *et al.*, 2014). Furthermore, the coating helps to delay senescence, which makes the commodity more vulnerable to pathogenic infection as a result of loss of cellular or tissue integrity (Tanada-Palmu and Grosso, 2005).Overall, the combination-coated tomatoes, particularly those with wax coatings, out performed single treatments by offering extended protection against disease incidence, making them ideal for prolonging shelf life.

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4.2 Microbial analysis

Table 10: Microbial analysis of Tomato with different coating materials.

S/N	Treatment	Plate count				Yeast and mould count						Coliform count			
		Acceptable limit (25-250cfu/ml)				Acceptable limit (10-150cfu/ml)						Acceptable limit (<10MPN)			
		Initial (day 0)		Final (storage termination date)		Initial (day 0)		Final (storage termination date)				Initial (day 0)		Final (storage termination date)	
		D3	D4	D3	D4	D3	D4	D4	D5	D6	D7	D3	D4	D5	D6
1	Control	2	Nil	10	2	Nil	Nil	11	3	Nil	Nil	Nil	Nil	Nil	Nil
2	Pectin	4	Nil	80	18	Nil	Nil	TNTC	20	4	Nil	Nil	Nil	10	7
3	Wax	Nil	Nil	8	Nil	Nil	Nil	38	18	Nil	Nil	Nil	Nil	Nil	Nil
4	Chitosan	20	4	120	95	Nil	Nil	55	7	2	Nil	Nil	Nil	Nil	Nil
5	P*W	1	Nil	7	6	Nil	Nil	130	25	Nil	Nil	Nil	Nil	3	Nil
6	P*C	15	18	107	55	Nil	Nil	12	2	2	1	Nil	Nil	Nil	Nil
7	C*W	15	Nil	5	Nil	2	Nil	2	Nil	Nil	Nil	Nil	Nil	Nil	Nil

**CFU - colony forming unit, MPN – most probable number, P*W=pectin with beeswax, P*C=pectin with chitosan, C*W= chitosan with beeswax. TNTC- Too Numerous To Count, D- Dilution.*

Microbial analysis was conducted to determine the efficiency of the coatings in successfully preventing microbial infection. Microbial growth can be influenced by water, pH, physical structure, oxygen and temperature. The table10 above shows the levels of microbial growth (including plate count, yeast and mold count, and coliform count) on tomatoes treated with various coating materials: control, pectin, wax, chitosan, and their combinations (pw, pc, and cw) over different storage days. Initially, uncoated tomatoes exhibit low microbial counts, but these levels increase over time, eventually exceeding acceptable limits for both plate count and coliform count. The results are presented in table 10 in which it can be observed that the total plate count increased significantly ($p \leq 0.05$) with time. This can be due to the changes in the environment as a result of minimal processing (Salinas *et al.,* 2016). There were also significant ($p \leq 0.05$) differences in the microbial growth between coated and other uncoated samples in which it can be observed that the presence of coating helped in reducing the rate of microbial growth. Beeswax prevents moisture permeation which greatly induced bacterial and fungal infection (Peñarubia *et al*., 2014). As for chitosan, it exhibited antimicrobial properties due to the interaction between the positively charged amino (–NH3) groups of chitosan and the negatively charged carboxylate (–COO–) groups on the surface of bacterial cell membranes (Bravo-Anaya *et al*., 2016). Tomatoes coated with pectin show moderate effectiveness at

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first; however, by later days, they record very high plate counts (too numerous to count, or TNTC) and yeast/mold counts, indicating limited ability to inhibit microbial growth.

In contrast, wax-coated tomatoes maintain microbial levels below acceptable limits in most categories, demonstrating effective protection against microbial growth. Chitosan-coated tomatoes initially control microbial growth effectively, but a significant increase in plate counts is observed during the later storage days, suggesting only partial inhibition capabilities. Combination treatments (pw, pc, and cw) generally exhibit better microbial control compared to single coating materials. The pw combination shows lower plate and yeast counts compared to pectin alone. The pc combination manages microbial counts moderately well, despite an increase in plate counts towards the end of the storage period. The chitosan and wax combination (cw) maintains minimal microbial growth, especially in coliform counts.

Furthermore, (El-Ghaouth *et al*., 1991) also reported that chitosan induces the development of chitinase that catalyses' chitin hydrolysis, this further confirmed that the combination of both of these compounds was capable of producing a stronger antimicrobial fruit coating that can extend the shelf-life of tomato fruits. Overall, wax-based and combination treatments demonstrate superior microbial inhibition, keeping counts closer to or below acceptable limits for extended storage periods.

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4.3 Sensory Attributes of Tomato

Table 11: sensory acceptability score of tomato coated and uncoated with different coating materials.

Treatment	Sensory attributes					
	Color	Firmness	Texture	Odor	Appearance	Overall acceptance
Control	6.18 ±2.136^{abc}	5.00±1.612^{a}	5.09±1.700^{a}	5.55±1.508^{a}	5.45±1.695^{a}	5.45 ±1.695^{a}
Pectin	7.55±1.214^{c}	6.64±0.924^{bc}	7.27±1.191^{c}	7.00±1095^{b}	7.18±1.662^{b}	7.18±1.662^{bc}
Beeswax	7.09±1.921^{bc}	7.36±1.567^{c}	7.18±1.471^{c}	7.45±1.214^{b}	7.27±1.421^{b}	7.64± 1.421^{c}
Chitosan	5.64±1.690^{ab}	5.45±1.214^{ab}	5.36±1.502^{ab}	5.55±2.115^{a}	5.55±1.508^{a}	5.82± 1.508^{ab}
P*C	6.82±0.874^{abc}	6.55±1.508^{bc}	6.64±1.206^{bc}	6.27±1.348^{ab}	6.36±1.362^{ab}	6.55± 1.362^{abc}
P*W	7.27±1.794^{bc}	6.55±2.018^{bc}	6.73±1.794^{bc}	7.55±1.368^{b}	7.18±1.168^{b}	7.18± 1.168^{bc}
C*W	5.27±2.149^{a}	5.64±2.157^{ab}	5.45±1.916^{ab}	5.27±1.555^{a}	5.09±1.640^{a}	5.18± 1.640^{a}

**The data were statistically analysed using Duncan's multiple range test (DMRT). Data represent the mean± standard deviation (SD) of the experiments. In the same column, significant differences at P < 0.05 level are indicated by different letters. (P*C=Pectin with chitosan, P*W=Pectin with beeswax, C*W=Chitosan with beeswax).*

Sensory analyses was performed by 11 panelists, to compare the external visual aspect and marketability of coated and control tomato fruit after 10 days of storage at 22 °C, , The panel was semi trained prior to the sensory evaluation of the tomato fruit. The panel initially assessed the preferences in treatments. For that, individual panelists were challenged to evaluate more than one fruit from each sample to ensure representative results. Samples of the different tomato products were coded and subjected to sensory evaluation by using 11semi trained panelists comprised of students in Food science and nutrition and laboratory assistants. The panelists were asked to assess each sample for its color, Firmness, Texture, Odor, Appearance and overall acceptability in a comfortable room with sufficient light and fresh air. Then panelists were asked to rate evaluation variables according to 9- point Hedonic scale as described by Larmond (1977).

The results obtained from the panelists were converted to scores ranging from: like extremely(9) to dislike extremely (1). Ask panel to rate the size of the difference between each sam ple and the control by providing a scale for this purpose. The control treatment has relatively lower scores across all sensory attributes. The values for color (6.18), firmness (5.00), texture (5.09), odor (5.55), appearance (5.45), and overall acceptance (5.45) are among the lowest in comparison to other treatments. qualities that might be given by coatings or additives. This result is expected since no added/more substances or treatments are used. Pectin coated tomatoes show higher scores for color (7.55), firmness (6.64), texture (7.27), odor (7.00), appearance (7.18), and overall acceptance (7.18). The values point to/show an improvement in sensory quality, especially in terms of texture and odor, suggesting that pectin plays a role in improving tomato attributes.

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Pectin is a natural polysaccharide known for its gelling properties, which can improve texture and preserve the appearance of tomatoes. Its positive influence on firmness and texture matches up with showing that pectin coatings help maintain product during storage (Zhao *et al.*, 2011). Beeswax-coated tomatoes also show improvement, especially in overall acceptance (7.64), firmness (7.36), texture (7.18), odor (7.45), and appearance (7.27). These values are (a) little higher than those seen with pectin treatment, suggesting beeswax as an effective treatment for improving sensory quality. Beeswax is commonly used in the food industry as a coating material to reduce moisture loss and extend shelf life (Huang *et al.*, 2014). The beeswax coating helps preserve the tomato's firmness, texture, and appearance, leading to a more favorable sensory profile. Chitosan-coated tomatoes show the lowest values in terms of sensory characteristics (Color: 5.64, firmness: 5.45, texture: 5.36, odor: 5.55, appearance: 5.55, overall acceptance: 5.82). These results suggest that chitosan, while effective in some application, may not significantly enhance the sensory properties of tomatoes when compared to other treatments. Chitosan has antimicrobial properties and is known to help extend the shelf life of fruits and vegetables (Kong *et al*., 2010). However, it may not be as effective as other treatments in improving the sensory quality of tomato, which may limit its practical application for improving the consumer experience. The combination of pectin and chitosan results in moderate improvements in sensory characteristics, with overall acceptance at 6.55, color at 6.82, and texture at 6.64. This combination shows a balanced effect on the sensory properties, though not as pronounced as pectin or beeswax treatments. Combining pectin and chitosan may offer benefits in terms of antimicrobial effects (from chitosan) and textural improvements (from pectin). However, the synergy between the two does not seem to surpass individual treatments, possibly because of the different functional properties they provide. Tomatoes treated with the combination of pectin and beeswax show promising results across all sensory attributes, especially odor (7.55) and overall acceptance (7.18). This combination leads to an improvement in texture and appearance, making it one of the top-performing treatments. The combination of pectin and beeswax provides the best of both worlds pectin improves texture and appearance, while beeswax helps with moisture retention and preservation. This studies aligns with showing that combined treatments can enhance the quality of fresh produce, including tomatoes (Rojas *et al*., 2013). The chitosan group combined with beeswax shows the lowest values across all attributes (color: 5.27, firmness: 5.64, texture: 5.45, odor: 5.27, appearance: 5.09, overall acceptance: 5.18). Despite the beeswax coating, it does not very much improve sensory quality when applied to uncoated tomatoes. While beeswax alone improves the quality of tomatoes, when applied to the uncoated control group, the benefits are not as significant. This hints that beeswax is more effective when applied to tomatoes that are already improved with other treatments like pectin.

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5 . CONCLUSIONS AND RECOMMENDATION

In summary, surface coating of tomato fruits using pectin, beeswax, chitosan and their combination solution can significantly delay changes in quality attributes such as proximate content (moisture, protein, fat, carbohydrate and crude fiber), weight loss, acidity, reducing sugar, total sugar, non-reducing sugar, TA, TSS, pH, acid ratio, ascorbic acid, lycopene content, and disease incidence and severity, which all together extended the shelf life of fruits during storage. Tomatoes collected at the turning stage were shown to have the longest shelf life when covered with pectin and then chitosan. Thus, coated tomato fruits had the longest shelf life while maintaining good quality. Extending tomato storage life may allow growers, distributors, and retailers to transport and market their produce for a longer period of time.

In conclusion, tomato fruits taken at the maturity stage and coated with combined treatment can effectively protect fruit quality and extend the shelf life of fresh tomato fruits. The edible coating approach appears to be quite promising, as long as customers accept it as safe. The coatings also provide the produce an appealing glossy sheen and may prevent against bruising and harm. As far as storage period is concerned as the storage period increase the quality parameters like pH, TSS, total sugar and reducing sugar increases gradually while parameters like acidity and vitamin content decreases.

According to sensory scores, Beeswax is the best treatment for tomato in terms of overall acceptance (7.64) with Pectin and Pectin + Beeswax closely behind. It improves most sensory properties such as firmness, texture, odor and color hence it is the best one to improve the overall sensory quality of tomatoes. The beeswax helps keep the skin of the tomatoes fresh, while also keeping moisture locked inside, thereby discouraging spoilage. Tomato sensory characteristic improvement indicates that beeswax coating; especially when used alone, gives the best results among other coating materials. However, the combination with beeswax might provide additional benefits, particularly in terms of textural improvement and maintaining the appearance.

Overall, for storage tomatoes, waxed fruits were preferred by consumers over unwaxed fruits. Such a glaze can be achieved by convincing farmers and traders to coat produce with locally available wax materials, thereby preserving the quality. It is recommended that there should be sensitization on the use locally produced wax to extent the shelf life of tomato for consumers and locally produced wax such as bee wax could be a good technology for preserving the quality and extending the shelf life of fresh tomatoes as well as maintaining the physical and chemical properties.

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Further combination studies are also necessary to examine the effect of coating materials with various types of packaging materials and storage temperature in order to further extend storage life and improve quality. The effectiveness of edible film coating materials on other fruit and vegetable produces, different varieties of tomato and at different maturity stages will be future researchable area.

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APPENDICES

Annex 3: Checklist for tomato sensory evaluation

Hedonic Scale Instruction

Objective

To evaluate sensory aspects of fully matured tomato on the basis of color, appearance, firmness, aroma/odor and overall acceptability.

Procedure

Please carry out the activities according to the steps enumerated herewith:

1. Take a moment and read out the instruction carefully
2. Write the panelist code and sample code of the sample provided at the top
3. Carry out your own personal sensory analysis for the given sample

Direction: please rate by checking the acceptance of each tomato sample provided with hedonic scale of 1- dislike extremely to 9- like extremely, as indicated at the score sheet below:

Score sheet

Date _____

Sample Code	**Sensory Attributes**	**Panelist's Response**								
		1	2	3	4	5	6	7	8	9
276	External color									
	Firmness									
	Texture									
	Odor/ Aroma									
	Appearance									
	Overall acceptability									
	Panelist's Response	1	2	3	4	5	6	7	8	9
347	External color									
	Firmness									
	Texture									
	Odor/ Aroma									
	Appearance									
	Overall acceptability									
	Panelist's Response	1	2	3	4	5	6	7	8	9
452	External color									
	Firmness									
	Texture									
	Odor/ Aroma									
	Appearance									
	Overall acceptability									
	Panelist's Response	1	2	3	4	5	6	7	8	9
296	External color									
	Firmness									
	Texture									
	Odor/ Aroma									

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	Appearance									
	Overall acceptability									
	Panelist's Response	1	2	3	4	5	6	7	8	9
653	External color									
	Firmness									
	Texture									
	Odor/ Aroma									
	Appearance									
	Overall acceptability									
	Panelist's Response	1	2	3	4	5	6	7	8	9
328	External color									
	Firmness									
	Texture									
	Odor/ Aroma									
	Appearance									
	Overall acceptability									
	Panelist's Response	1	2	3	4	5	6	7	8	9
523	External color									
	Firmness									
	Texture									
	Odor/ Aroma									
	Appearance									
	Overall acceptability									

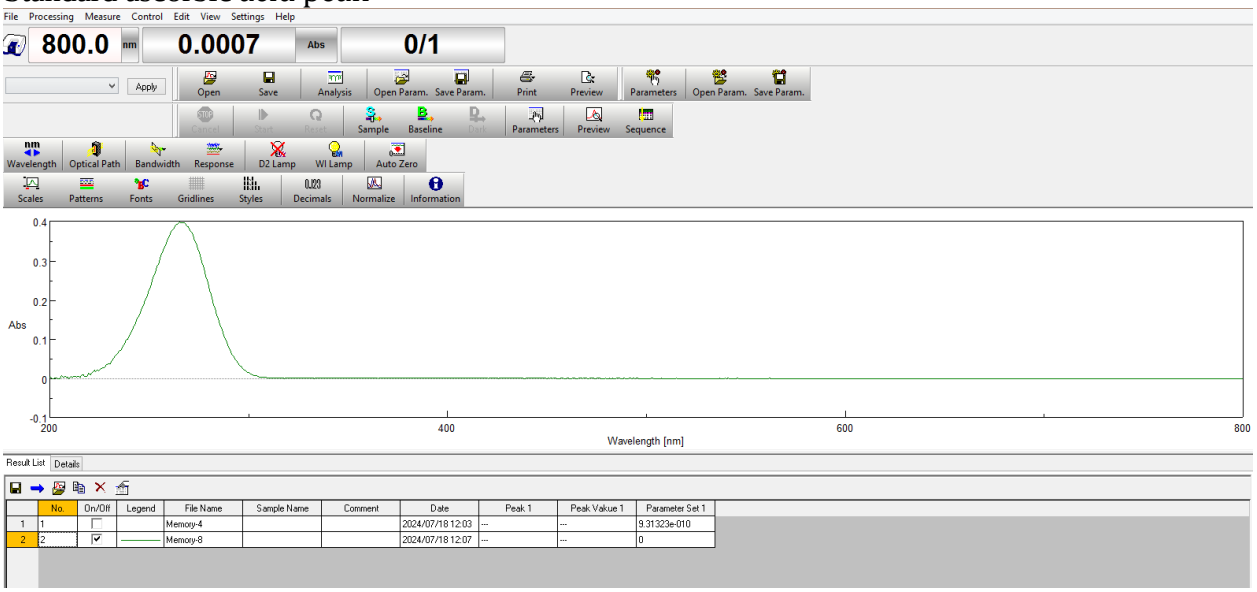
Comments:_____

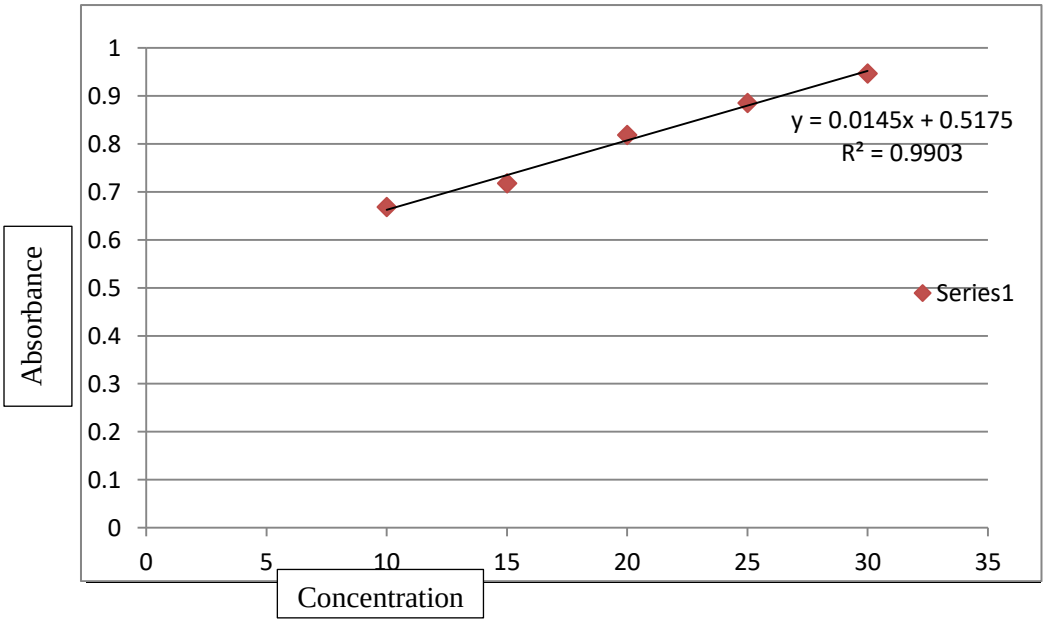
Note: 1= Dislike Extremely, 2= Dislike Very Much, 3= Dislike Moderately, 4= Dislike Slightly, 5= neither Like nor Dislike, 6= Like Slightly, 7= Like Moderately, 8= Like Very Much, 9= Like Extremely .

Thank you in advance for your valuable contribution

.

Standard ascorbic acid peak





Figure…. Calibration curve of ascorbic acid.

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Declaration

I, the under signed, declare that this is my original work and has never been presented in this University or any other University and that all sources of material used for this master thesis have been duly acknowledged.

Author's name: Ibrahim Abebe

Signature_____

Date _____

Place: Addis Ababa University, Center for Food Science and Nutrition, Addis Ababa-Ethiopia

Date of submission_____

The research thesis has been submitted for examination with my approval as University advisors.

Advisors

Dr Paulos Getachew

Signature _____

Date _____