PERFORMANCE OF CARBOXYLMETHYL CELLULOSE COATING INCORPORATED WITH PLANT OILS ON THE PHYSICAL, AND CHEMICAL CHARACTERISTICS OF *PAPAYA* (*Carica papaya L.*) STORED DIFFFERENTLY

BY

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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MPHIL IN CROP SCIENCE DEGREE.

COLLEGE OF BASIC AND APPLIED SCIENCES

DEPARTMENT OF CROP SCIENCE

UNIVERSITY OF GHANA, LEGON

JANUARY, 2023

DECLARATION

I, MATILDA A. D. AFFUL, do hereby declare that except for references cited which have been duly acknowledged, this thesis **“Performance of Carboxylmethyl cellulose incorporated with plant oils on the physical, and chemical characteristics of *Papaya* (*Carica papaya l.*)’’** is the result of my own research. It has never been presented either in part or in whole for the award of any degree.

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14/09/2023

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Dr. Seloame Tatu Nyaku (Co-supervisor) Date

DEDICATION

I dedicate this thesis to God, my mum Grace Bilson and husband Benjamin Afful.

ACKNOWLEDGEMENT

First, my gratitude goes to God for seeing me through this study.

My sincerest gratitude goes to Dr. (Mrs.) Gloria Essilfie and Dr. Seloame Tatu Nyaku; my supervisors for their guidance and support in completing this work.

My deepest appreciation goes to my mum and husband, Grace Bilson and Benjamin Afful for their encouragement, prayers and support throughout this study.

A special acknowledgement to CBAS, University of Ghana for study leave and financial assistance.

Lastly, to Mr. Bernard Boateng, Mr. Duke Mensah, Mr. Samuel Kwatia and Mr. Richard Otoo for their assistance and support.

LIST OF ABBREVIATIONS

CBAS	College of Basic and Applied Sciences
CMC	Carboxylmethyl Cellulose
TTA	Titrable Acidity
TSS	Total Soluble Solids
MO	Moringa Oil
NO	Neem Oil
EBDC	Ethylene Bisdio-thiocarbamate
MA	Modified atmosphere
CA	Controlled Atmospheres
CV	Cultivar
CO_2	Carbon dioxide
C_2H_4	Ethylene
RH	Relative Humidity
PDA	Potato Dextrose Agar

ABSTRACT

Papaya is an important fruit for both fresh and processed products. It is an excellent source of nutrients vitamin A. According to reports, postharvest spoilage causes 30 to 50 percent of harvested papaya to never reach consumers. The perishability of papayas after harvesting is a contributing factor in postharvest spoilage. The level of spoilage depends on postharvest management practices. *Papaya* is also susceptible to numerous postharvest fungal diseases.

To reduce postharvest spoilage, numerous fungicides have been used. However, the negative effects on human health and the environment, combined with high costs, have prompted the development of alternative approaches.

Phase 1 was the evaluation of the postharvest handling and management practices of *Papaya* along the *Papaya* value chain in the Nsawam-Adoagyir district at Nsawam. Ninety open and close ended questionnaires were administered to farmers and traders of *Papaya*. Farmers dealers (transporters, sellers) and consumers are the key players along the value chain. Major losses incurred on the farm during harvesting (65.9%). The main cause of losses was poor handling, rot and physiological disorders. Traders on the other hand incurred major losses from storage (52.3%). due to rot and rodents during storage. Majority of farmers (92.5) and traders (75) did not have knowledge on edible coating but were open to the innovation and use of edible coatings.

Secondly, this study examined the effectiveness of carboxymethyl cellulose and its combination with moringa and neem oil in enhancing the quality and extending the shelf life of *Papaya*. Treatment combinations of CMC, CMCNO, CMC3NO, CMCMO, CMC3MO, MO, 3%MO, NO, 3%NO, 0.3%Pro were applied and assigned to ambient and refrigeration temperature (10°C) conditions. Edible coatings had significant effect in maintaining quality of *Papaya* fruits compared to the controls under both storage conditions. However, refrigeration

temperature (10°C)-maintained fruit quality and prolonged shelf life compared to ambient storage. *Papaya* under ambient and refrigeration temperature (10°C) lasted 9 and 21 days respectively. The application of 1% CMC, 3% Pro and 1%CMCNO coatings caused *Papaya* stored at ambient temperature to last 15 days and 27 (additional days) days refrigeration temperature respectively. 1%CMCNO was able to maintain most quality attributes and also reduce disease incidence.

Lastly, fungal pathogens associated with *Papaya* rot were isolated, identified and pathogenicity evaluated using morphological structure through recommended books. *Aspergillus flavus, Collectotrichum gloeosporoides*, *Fusarium* spp., *Lasiodiplodia theobromae*, *Penicillium* and 'Fante kenkey fungus' (unidentified) were identified and pathogenicity evaluated. Treatment 1%CMCNO proved effective with the least (36.6%.) significantly different disease incidence compared to the control with the highest (76.6%) disease incidence.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Papaya (*Carica Papaya L.*) is a member of *Caricaceae* family (Antunes Carvalho & Renner, 2012).According to Julianti *et al.* (2014), *Papaya* is a nutritious fruit that is widely consumed in tropical and subtropical regions around the world as fresh and processed product. It is an excellent source of vitamin A. *Papaya* Contains complex carbohydrates that provide energy and help to regulate blood sugar levels, and proteins, essential for growth, repair, and maintenance of body tissues (Waghmare & Annapure, 2013) Additionally, epidemiological studies have found anti-inflammatory and antioxidant properties, which helps to reduce the risk of certain types of cancer and reduced risk of heart disease respectively (Gayosso-García Sancho *et al*., 2011).

The global market for tropical fruits, including papaya, has grown significantly due to a variety of factors, such as increased demand for exotic food and advances in transportation and storage technologies for fresh produce. This has made it possible for consumers in many parts of the world to enjoy these fruits year-round (Elhadi M Yahia, 2008).

In Ghana, papaya is cultivate on a large scale in four regions: Greater Accra, Central, Eastern, and Volta, and its export potential is widely recognized (FAO & CIRAD, 2021). Since the early 2000's *Papaya* has been receiving much attention among commercial farmers and exporters. Amidst challenges posed by diseases, postharvest handling and storage, import standards, taxes and recently COVID 19 pandemic, there has been an upward trend in the value of *Papaya* exports in Ghana since 2016. In 2016, 475tons of *Papaya* fruits valued at 125000 United States dollars ($) was exported, 1333 tons valued at 899000 $ in 2017, in 2018 and 2019, 1358 and 1454 tons respectively were exported valued at 985000 $, a total of 2056 tons valued at 1714000$ in 2020 was exported to Europe (FAOSTAT, 2021). This demonstrates that there is still a sizable market for *Papaya* exportation if proper cultivation, handling and storage practices are followed.

Papaya is a climacteric fruit which continues to ripen after harvest. As a result of their increased perishability, the fruits encounters significant postharvest problems during handling and storage (Vyas *et al.*, 2014). High perishability results in more waste, fewer fruits reaching consumers, and higher fruit prices. The short postharvest life of the fruits manifest in quality and quantity loss (Waghmare & Annapure, 2013). These losses significantly affect farmers' and traders' income and food security. Papaya fruits are susceptible to varied diseases and physical disorders (González-Aguilar *et al.*, 2003). According to Hasan et al., (2012), papaya diseases are caused by a variety of microorganisms, most notably fungi from the genera, *Colletotrichum, Phomopsis, Phytophthora, Rhizopus, Stemphylium* and *Fusarium*. The most important among them that causes extensive postharvest losses in *Papaya* fruits is *Colletotrichum gloeosporioides*. This fungus causes anthracnose disease (Sivakumar *et al.*, 2002; Gonzalez-Aguilar *et al.*, 2003; Hasan *et al.*, 2012).

1.2 Justification

Papay*a* is of important value to the economy of Ghana in terms of internal and export markets. In 2021, an estimated 5644.96 tons of papaya was produced in Ghana and out of this was an export volume of 3.60 million metric tons valued at 2.75million. However, papay*a* has a short postharvest life. It is therefore, imperative that the shelf life of harvested papaya be looked at intensely and improved by every means. It becomes absolutely essential when the technology being conceived is of natural origin, environmentally friendly and safe, and the materials required can largely be sourced locally. Currently, research efforts are being directed at edible coatings of tropical fruits to help extend shelf life of many such fruits by assessing the efficacy of these coatings, especially those containing antimicrobials (Ayala-Zavala *et al*., 2008; Carrión-Granda *et al*., 2016).

Coating film formers consist of polysaccharide, protein, lipids, resins, alone, or in combination. Polysaccharides are one of the major and abundant coatings that includes; alginate, pectin, chitosan and derivates of starch and cellulose. Advances in antimicrobial edible coatings for fruits have also shown to extend the shelf life, food safety and quality requirements. These coatings include polysaccharides incorporated with essential oils or proteins (Bautista-Baños *et al*., 2013; Martins *et al*., 2010)

Carboxymethylcellulose (CMC) is derived from cellulose and enhances quality and lengthen the fruit's shelf life when used as an edible fruit coating (Baldwin & Wood, 2006). CMC powder, which is commercially available, is white to cream-coloured and bland with numerous applications in the food industry, including use as thickeners, binders, to improve texture, as edible films, and coatings. (Dashipour *et al*., 2014; Rachtanapun, 2009). By creating a semi-permeable membrane, CMC has proved to lengthen fruit storage life when applied to fruits. This membrane slows down fruit deterioration by reducing metabolic processes, ethylene production, and disease infection (Elsabee and Abdou, 2013). Plant-based preservatives do not adhere well to fruit surfaces, their incorporation into coating materials makes them an ideal postharvest treatment for extending shelf life and improving fresh produce quality. (Tesfay *et al*., 2017). CMC coatings have been used to reduce respiration rates of avocados and to preserve their physical and chemical qualities during storage. In this study, control fruits lasted 6 days whiles 1%CMC coated fruits lasted 10 days at 25°C (Maftoonazad & Ramaswamy, 2005). Vyas *et al*., (2014), reported retention of original firmness and crispness of apples, berries, peaches, celery, lettuce, and carrots when CMC is used as powder coating

Moringa (*Moringa oleifera Lam*.) is a tropical and subtropical tree that grows throughout the world. Moringa oil has been proven in studies to have high antioxidant and antipathogenic activity against a variety of microorganisms (Yousef et al., 2015) . According to Rao *et al.* (2001) the antipathogenic properties of moringa are due to its potent phytochemicals which include sitosterol, niacin A, stigmasterol, kaempferol and quercetin. Tesfay and Magwaza (2017), discovered that treating 'Hass' and 'Fuerte' avocado fruit with 1% CMC (w/v) containing moringa oil in room temperature demonstrated enhanced fruit quality and a longer shelf-life.

Neem (*Azadirachta indica*) is a common tree that is primarily grown in the Indian subcontinent Many parts of the tree have been used in indigenous herbal medicine in India (Brahmachari, 2004). There is proof that neem oil has acaricidal and antimicrobial properties (Brahmachari, 2004; Gossé *et al*., 2005; Mulla & Su, 1999; Zhang *et al*., 2010) Due to its potency and minimum side effects, *Azadirachtin,* has emerged as a natural biopesticide, a quality which can be explored in increasing the shelf life of fruits after harvest (Ezeonu *et al*., 2018).

Generally, temperature has a significant impact on the shelf life and quality of fruits. High temperature (above 30°C) increases rate of respiration and microbial growth which leads to spoilage and low temperature (below 10°C) creates cold injuries rendering food unmarketable (Nunes *et al*., 2013). Refrigeration (10 to 13°C) is important in the preservation of food quality and extension of shelf life. At room temperature (22.5 to 27.7°C) *Papaya* ripen from 2 to 6 days at colour break stage (An & Paull, 2019). When refrigerated, *Papaya* can be kept for up to 14 days. Pre storage treatments and technologies are therefore employed to improve storage which reduces losses of *Papaya* fruits(Paliyath & Padmanabhan, 2018).

Several authors have thoroughly researched and documented the use of edible coatings for extending the shelf life of fruits. (Dashipour *et al*., 2014; Vyas *et al*., 2014; Vipan *et al*., 2018;

De Vasconcellos Santos Batista *et al*., 2020; Farina *et al*., 2020). However, the use of CMC to extend the shelf life of papaya has not been thoroughly researched. To capitalize on the global papaya market, it is imperative to investigate the use of CMC and locally accessible plant oils, as well as its possibility of extending the shelf life of *Papaya* while maintaining its quality

Already, the use of moringa as bio preservative has been well studied in other fruits (Rao *et al*., 2001; Adetunji *et al*., 2013 Tesfay *et al.*, 2017; Langa, 2018). However; the synergistic use of CMC and moringa oil, as well as CMC and neem oil has not been studied in Ghana.

1.3 Objectives of the study

The main objectives of this research is to;

Evaluating the postharvest handling practices along the *Papaya* value chain and the effectiveness of locally available plant oils in combination with carboxymethyl cellulose to enhance quality and extend shelf life of papaya under different storage temperatures

Specific objectives are;

- Evaluate postharvest handling practices along the *Papaya* value chain in the Nsawam-Adoagyir district at Nsawam.
- Examine the effectiveness of carboxymethyl cellulose and its combination with moringa and neem oil in enhancing the quality and extending the shelf life of *Papaya*.
- Isolate, identify and evaluate the pathogenicity of organisms associated with postharvest diseases of *Papaya*

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin/History

The papaya-producing *Carica papaya* plant is indigenous to the American tropics and was originally domesticated in Mexico (De Oliveira & Vitória,n 2011). Although perspectives on the origin of *C. papaya* in tropical America differ, it is most likely to have come from the lowlands of Eastern Central America (Mexico) to Panama. During Spanish expedition in the 16th century, it is believed that pawpaw seeds were dispersed to the Caribbean and south-east Asia, from where it quickly spread to the Pacific, India, and Africa. The Spanish chronicler Oviedo first reported of *Papaya* in 1526, after discovering it on the Panamanian and Colombian coasts (De Oliveira and Vitória, 2011). As a result of its numerous, extremely viable seeds, the fruit spread quickly in the tropics and because of the good soils and sufficient rainfall in the tropics, the crop adapted effectively.

2.2 Taxonomy/Description

Papaya belongs to the *Caricaceae* family, which has four genera and thirty-one (31) species. The only genus in the family with species of edible fruit is *Carica*, which has twenty-two (22) species(Esguerra *et al*., 2020). While *C. chilensis*, *C. gouditiana*, *C. monoica, and C. pubescence* species are primarily used as vegetables, *Carica Papaya* species are consumed as fruit. *C. papaya* grows to a height of 3 to 10 meters. The tree has a strong fibrous root structure and a fleshy, hollow stem. *Papaya* tree (Prasad & Paul, 2021; Vijayan *et al*., 2015). It is characterized by the palm's growth pattern, which creates scars on the stem where leaves have fallen off. All *Caricaceae* members are deciduous, although the three species; *C. monoica, C. pubescence*, and *C. papaya* vary widely from one another. Male, female, and hermaphrodite are the three fundamental sex types found in the species *Carica papaya* (Vijayan *et al*., 2015).

The *Papaya* fruit typically consists of five carpels that are joined to create a central cavity that houses the seeds. Fruit seeds may have star-shaped or rounded cavities (Yogiraj *et al*., 2014).

When fully developed and encased in a sacrotesta, the seeds are black. Fruit can be cylindrical, spherical, or pyriform (pear-shaped). Fruits range in size from 200 g to 10 kg, and their flesh can be 1.5 to 4 cm thick. Depending on the cultivar , the flesh changes from greenish-white fruit to a mild orange-yellow, salmon-pink, or red colour when ripe. (Rathod & Chavan, 2012; Yogiraj *et al*., 2014).

2.3 Cultivation

Papaya is grown from seed in a well-drained, fertile soil with a pH of 6-6.5 Before planting, the seeds must be extracted from their gelatinous coating for optimum germination (Zaria D., 2016). The seeds should be air-dried to ensure their viability for the next 2-3 years. Germination of seedlings takes 8-10 weeks before transplanting to the field. Papaya is a tropical plant, it is vulnerable to cold and so needs full light for good growth (Zaria D., 2016). For best fruit production, *Papaya* requires rainfall of 100 mm per month , relative humidity of 66 %, and temperatures ranging from 21℃-33℃ (Hare *et al*., 2000)

Five to eight months from seed germination *Papaya* fruits are ready for harvest (Hare *et al*., 2000; Organisation for Economic Co-operation and Development (OECD), 2003). An average fruit weigh between 250 and 3000g. When the first signs of yellow colour develops on the skin, papay*a* fruits are ready for harvest and will ripen in 4-5 days (Hare *et al*., 2000; OECD, 2003).

2.4 Varieties

Fruits come in a variety of physical characteristics and eating qualities due to improved varieties. There are numerous *Papaya* types available, and they are typically named based on its geographic origin and preferred flavor, such as "Subang," "Sitiawan," "Batu Arang," "Koko," "Sunrise," "Maradol," "Solo," "Eksotika," and "Taiwan." The newly introduced fruit varieties "Solo" and "Eksotika" are small and have pyriform or circular shape (Bautista-Baños *et al*., 2013). In Ghana, local varieties have been cultivated for a long time. However, the Hawaiian solo types were introduced in the early 1990s and this type is the core of the export crop.

2.5 Nutritional Composition of *Papaya* Fruit

According to Zaria D. 2003, papaya fruits contain roughly 88 percent water, 10 percent sugar, 0.5 percent protein, 0.1 percent fat, 0.1 percent acids, 0.6 percent ash, and 0.7 percent fiber per 100 g of edible portion when they are fresh and ripe. A potent source of vitamins A, E, pantothenic acid, folate, and C, papayas also have high levels of magnesium, potassium, calcium, and dietary fiber, papain and chymopapain (Daagema *et al*., 2020). Both papain and chymopapain have the ability to breakdown protein and help milk coagulate (Kilmer, 2010; Dharini Sivakumar & Wall, 2013). Sucrose, glucose, and fructose are the main sugars, with total sugar concentrations ranging from 7.5 to 13.7 g/100 g FW (Alabi *et al*., 2012. The red-fleshed *papaya* fruit contains carotene, cryptoxanthin, carotene-5-6-epoxide, lycopene, and carotene, whereas the yellow-fleshed *Papaya* contains carotene, cryptoxanthin, and carotene (Bender, 2013; Kamelia *et al*., 2019; Thompson, 2003)

2.6 Utilization

Essentially, every part of the *Carica papaya* has monetary value. The advantages range from domestic to industrial uses. Papaya fruit is traditionally eaten like a melon, in desserts and salads, and is also used in the production of confectioneries, wines and crystallized fruits(Saran & Choudhary, 2013). Basalingappa M. K. (2018), opines papaya seeds have a peppery flavour and can be dried, ground, and used as a pepper substitute The seeds are also useful in the treatment of anaemia, poisoning disorders and in the relief of nasal congestion (El Moussaoui *et al*., 2001). Papaya leaves is used in the treatment of ailments including, indigestion, heart diseases , fibroids, tuberculosis, malaria and obesity (Yogiraj *et al*., 2014). Papain, the milky latex, has a wide range of applications in the food, cosmetics textiles and pharmaceutical industries, including the manufacture of chewing gum, chill-proofing beer, and meat tenderizers (Adachukwu *et al*., 2013; Yogiraj *et al*., 2014).

2.6 Postharvest factors influencing quality and shelf life

2.6.1. Handling

Postharvest losses can occur as a result of poor handling (Ali *et al*., 2010; Kasso & Bekele, 2018). Fruit surfaces are easily wounded so, proper postharvest handling procedures are required. (Bautista-Baños *et al*., 2013). This includes separating fruits with symptoms of postharvest disease from healthy fruits.

2.62 Pre-cooling

Pre-cooling is the process of removing field heat right away after harvesting in order to slow down the metabolism to delay fruit deterioration. Pre-cooling and reduced susceptibility to bruises are positively correlated (Tahir *et al*., 2009). *Papaya* fruit that had been pre-cooled with cold water had less moisture loss than the control, according to Tsado (2012). Additionally, it was noted that pre-cooled fruit colours changed much later than the control, with enhanced fruit flavour and aroma.

2.6.3 Packaging

Good packaging, aids in significant reduction in fresh fruit and vegetable waste. Furthermore, good packaging protects against mechanical damage, unfavorable physiological changes, and pathological deterioration in the handling of fruits (Kutama *et al*., 2007; Yahaya, 2019). Most developing countries use various containers such as wooden boxes, corrugated fiber board boxes, jute bags, bamboo baskets, and earthen pots.

2.6.4 Transportation

According to Prasad & Paul, (2021), it is one of the most crucial steps in the supply chain because unsuitable transportation causes immense amount of produce waste. For the sale and distribution of fresh produce to be successful, a swift and efficient transportation system is required. Loading and unloading should be done carefully in a clean, ventilated and top covered vehicle. Crops should be transported carefully during the cool part of the day to minimize damage to crop. Vehicles hauling harvested crops from field to market should be equipped to mitigate the shocks and vibration on the road.

2.6.5 Storage

Low-temperature (10-13℃) storage extends the storage life of papaya after harvest while preserving its nutritional value and quality characteristics (Thompson *et al*., 2018). Also, at lower temperatures, a number of enzymes involved in biochemical synthesis are inhibited. Fresh papaya's respiration rate, which reflects its rate of perishability, is directly impacted by temperature (Milie *et al*., 2005). The respiration rate roughly doubles for every 10 degrees Celsius increase in temperature, and the primary metabolic are depleted more quickly. *Papaya* storage life is reduced at higher temperatures according to Sivakumar & Wall (2013). The rise in CO_2 and C_2H_4 production as a result of ripening is slowed by low-temperature storage. In order to increase shelf life, *Papaya*s should be stored at 10 °C. Fruit stored below 10 C may experience chilling injury, while fruit stored above 10 C will ripen and soften more quickly ((Prasad & Paul, 2021). It is advised to store the fruit at 90 to 95 percent RH. High RH, however, may encourage the development of decay, particularly if moisture condenses on the fruit for an extended period of time when temperatures change during transportation. Ideal temperature and RH must be maintained to effectively preserve overall fruit quality.

2.6.5 Marketing

It is common to lose money when selling fruits and vegetables, to also make a profit is attainable when the market most needs the product. Marketing fresh perishables, however, is more difficult than marketing other agricultural products with a long shelf life. Losses can be avoided by using a ready market or prearranged market. There is a lot of waste and loss during the peak of the season, when the market is glutted with a particular vegetable or fruits. Prices are very low, discourages and demoralizes farmers. As a result, efforts should be made to avoid glutting, and limit losses by preservation or processing. (Yahaya, 2019; Yahaya *et al*., 2016)

2.6.6 Processing

Dehydration, canning, and freezing are common methods of preserving fruits and vegetables in developed countries. Sun drying or dehydration is the most basic and cheapest method of preservation which should be widely used in developing countries like Ghana considering the abundance of the sun all year round (Atanda *et al*., 2011). Overall, there are many different ways to preserve fruits and vegetables, and the best method will depend on the specific needs and resources of the individual or community.

2.7 Diseases of *Papaya*

Postharvest diseases degrade fruit quality resulting in significant losses. Postharvest diseases on fruit can be exacerbated by high moisture and unsuitable storage temperatures. Fungal pathogens enter the fruit through surface wounds. Damaged fruit must therefore be separated during the grading and sorting process.

2.7.1 Anthracnose

Anthracnose is a major postharvest disease of papaya caused by *Colletotrichum gloeosporioides*. *C. gloeosporioides* field inoculum is derived from dead infected petioles of the lower leaves (Hernandez-Montiel *et al*., 2018). During wet weather, the disease becomes more severe. Splattering rain carries spores of C. gloeosporoides to developing fruit by wind. The spores grow appressoria and infect the fruit when exposed to moist conditions. Symptoms do not manifest until the fruit reaches it ripening peak of ripeness (Bosquez-Molina *et al*., 2010).

2.7.2 *Fusarium* fruit rot

Fusarium rot causes large, slightly depressed lesions to. Water-soaked lesions are the first signs of the disease, and soon after, circular depressed spots appear. Fruit surface develops a white mycelial fungus growth when it is moist. (Helal *et al*., 2018).

2.7.3 Stem end rots

Lasiodiplodia theobromae, *Mycosphaerella caricae,* and *Phoma Caricae-papaya* are the three organisms that cause stem-end rots. These fungi establish themselves and remain dormant beneath the cuticle throughout fruit development. L. theobromae produces white to dark sunken lesions over time. Some fungi enter through mechanical wounds, like a broken peduncle from harvesting s(Vawdrey et al., 2015).

2.8 Disorders

Papaya disorders/abnormalities are related to environmental factors, which are difficult to prevent and others due to preharvest nutritional imbalances (Kader, 2002). The most common disorders of *Papaya* are; skin freckles, pulp translucency, pulp softening and hard lumps in the pulp (da Silva Pereira *et al*., 2012; de Oliveira & Vitória, 2011).

2.8.1 Mechanical injuries

Careless handling while harvesting, packing, transporting, and storing produce can lead to mechanical damage. The mechanical damage to fruits and vegetables is also caused by some insects and birds. In many cases, mechanical damage to fruits like bruising and cracking makes them more vulnerable to organism attack and accelerates the rate of water loss and gas exchange. Even though it is frequently invisible, the mechanical damage brought on by pressure thrust during transportation ruptures tissues and cells of fruits. Such produce degrades more quickly as it ages naturally (Jayasheela *et al*., 2015).

2.8.2 Chilling injury (CI)

Papaya fruits is susceptible to chilling injury if kept at temperatures below 10 °C. Chilling injury is characterized by sunken lesions on the fruit, discolouration of the peel and the flesh, inability to ripen (Vyas *et al*., 2014).

2.8.3 Insect Pest

Fruit flies are insects that reduce papaya's commercial viability. Surface pests like scales, mites, aphids, thrips, leafhoppers, or whiteflies also cause damages that deteriorates fruit quality

2.9 Postharvest treatments

Pre-storage treatment is crucial in maintaining the quality of fruits and vegetables and preventing the spread of infection before fruits are stored for the preferred length of time. (Langa, 2018). The several pre-storage treatments include;

2.9.1 Chemical control

To chemically control postharvest diseases of papaya, a number of fungicides from the benzimidazole, imidazole (Prochloraz), and ethylene- bisdiothiocarbamate (EBDC) groups are used. The effectiveness of these fungicides depends on a number of factors, including dosage, papaya ripening stage, sensitivity response of the targeted fungi, application timing, and others. The most widely used post-harvest fungicides belong to the benzimidazole group with disease control rates of up to 50%. *C. gloeosporioides, Lasiodiplodia theobromae, Alternaria alternata, R. stolonifer, and B. theobromae* are among the most studied fungi (Bautista-Baños *et al*., 2013; da Silva Pereira *et al*., 2012; Paull *et al*., 1997). In order to effectively combat this, it is common practice when handling *Papaya* to combine fungicides at lower concentrations with other non-chemical solutions like waxes/coatings and hot water/vapor.

2.9.2 Heat treatment

Hot-water immersion, vapor heat, and forced hot air are alternative disease control methods for fruits and vegetables (Manrique & Lajolo, 2004). By directly affecting the viability of the spores at the surface or below and delaying conidia germination, growth, and sporulation, this convection-heating medium effectively eliminates early infections (Fallik, 2021). Spray, hot water immersions, and forced-air heat treatments have been used in this situation to successfully control stem-end rots and the anthracnose disease of *Papaya* fruit (Manrique & Lajolo, 2004; D. M. S. Martins *et al*., 2010). Chávez-Sánchez *et al*., (2013) observed a delay in the appearance of disease symptoms in *Papayas* treated at 55°C for 3, 6, and 9 minutes for up to 11 days.

2.9.3 Irradiation

Food irradiation is the process of exposing it to a controlled dose of ionizing radiation for a set period of time, whether packaged or in bulk. Irradiation is currently used to control insects in quarantine for a variety of perishable goods. Irradiation is still being tested as a way to prevent postharvest disease. According to studies evaluating the quality of post-harvest papaya fruit after irradiation, ripening is delayed due to higher fruit firmness during storage. Further research with papaya by Cia *et al*., (2007) revealed that the best gamma irradiation dose in that study was 1.0 kGy when *C. gloeosporioides* was inoculated 10 hours prior to radiation application.

2.9.4 Edible films and coatings

Edible coatings halts microbiological (Hasan *et al*., 2012), chemical, and physical processes (Irtwange, 2006; Osae *et al*., 2017), edible coatings made of polysaccharides have shown to increase the shelf life of fruits and vegetables while also preserving their nutritional and sensory qualities. They exhibit unique barrier protection that prevents gaseous exchange and moisture from being absorbed. Carboxymethylcellulose (CMC) is a widely used cellulose derivative with the ability to form transparent films, and high mechanical strength (Rachtanapun, 2009) and biodegradable(Rachtanapun, 2009). When incorporated with antimicrobials, they reduce antimicrobial diffusion, resulting in a longer shelf life and higher fruit quality when compared to the simple application of the antimicrobial (de Oliveira & Vitória, 2011; Zillo *et al*., 2018). A study by Langa, (2018), confirmed this when CMC incorporated with moringa extract delayed deterioration of physical qualities and inhibited *Papaya* diseases under different storage conditions. Natural antioxidants like essential oils also have antimicrobial and biodegradable qualities with no lasting effects on fresh produce (Bautista-Baños *et al*., 2013). They are volatile substances created by plants' secondary metabolism that combats fungal phytopathogens (Bautista-Baños *et al*., 2013).

2.9.4 Modified and controlled atmospheres

Modified and controlled atmospheres (MA and CA, respectively) employs the technique of a mixing gases to replace the atmospheric gas inside the package or container, resulting in extension of shelf life of some fruits and vegetables. There are findings regarding the benefits of this technology on disease control in *Papaya* fruit.. Carrington *et al*., (2011) reported effective control of postharvest rots and significantly less weight loss for the cv. 'Tainung 1', after CA storage for 35 days at 16 °C. Rohani & Zaipun, (2007) reported similar beneficial effect with cv. 'Eksotika.'

2.10 Physical properties

2.10.1 Firmness

Fruits and vegetables' textures are often described in terms of their firmness, crispness, juiciness, and toughness (Shim et al., 2018). The texture of fresh produce is an important component of its acceptability (Brishti *et al.*, 2013). Texture influences shelf life, transportability, and disease resistance (Manrique & Lajolo, 2004). The basic determinants of fruit quality and postharvest shelf life during storage are the rate and delay of firmness loss (Brishti *et al.*, 2013). Fruits become softer as a result of degrading cell wall in the middle lamella (Brishti *et al.*, 2013).The combined effects of enzyme hydrolases change the composition and structure of cell walls (Brishti *et al.*, 2013).

2.10.2 Weight loss

According to Espitia *et al.*, (2012), weight loss has a significant impact on the quality and shelf life of *Papaya* fruit. High storage temperatures, skin removal, and cutting, which expose interior tissues and significantly speeds up water evaporation, are the main causes of fruit weight loss. The primary causes of fruit weight loss are respiration and transpiration (Langa, 2018). During respiration and transpiration, the fruit loses water and carbon reserves, respectively (Espitia *et al.*, 2012). The water pressure gradient between the fruit tissue and the surrounding atmosphere determines the rate of water loss. (Langa, 2018).

2.11 Chemical properties

2.11.1 Total soluble solids (TSS)

Fruits sugar is the main content of ripe fruits and (Ngnambala, 2013)(Lin & Zhao, 2007). This usually has to do with the presence of sucrose, glucose, and fructose, which are frequently used as ripening markers (Langa, 2018). This is due to the fact that as the fruit ages and ripens, its TSS content rises. As a result, the fruit's soluble solids content serves as a reliable gauge of maturity or ripeness (Ngnambala, 2013).

2.11.2 Total titratable acidity (TTA) and pH

Fruit pH values show how acidic or alkaline the product is (Ngnambala, 2013). Titratable acidity measures how much acid is present in a specific product. Fruits' ability to balance their flavours depends on their acidity and sugar which determines its taste. Typically, as fruit ripens, the acid content decreases (Lin & Zhao, 2007). Citric, malic, alpha-ketoglutaric, and ascorbic acids make up *Papaya*'s total acid content, contributing to a low acidity level (Martins & de Resende, 2013).

2.1.2 Shelf-life

The maximum period of time after removal from the mother plant during which food is safe to consume and has an acceptable taste, texture, and appearance shelf-life of the product (Huber & Embuscado, 2009). Fruit shelf life is affected by respiration, biological structure, ethylene production, sensitivity, transpiration, developmental processes, and physiological breakdown (Parmeshwar Lal Saran *et al*., 2016).

2.12 Postharvest losses of Papaya

Between the time of harvest and when it reaches the consumer, two types of postharvest losses take place. These losses are quality losses and quantitative losses.

2.12.1 Quality losses

The degree to which a product conforms to a desired standard is referred to as its quality. Therefore, when a product or commodity does not meet the preferred standard quality is lost. Papay*a* fruits of high quality are pyriform (pear-shaped), spherical, or cylindrical, with flesh thickness ranging from 1.5 to 4 cm. When ripe, the flesh changes from green immature to pale orange-yellow, salmon pink, or red depending on the cultivar. Physical injuries diseases, decay, colour change, flavour change, texture change, physical and pathological disorders are examples of quality losses associated with *Papaya*.

2.12.2 Quantitative losses

Quantitative losses reflect a reduction in the produce's initial weight over time. *Papaya*s lose weight basically as a result of water loss through the skin. Fruit weights range between 200 g and 10 kg. Cuticle thickness, fruit maturity, storage conditions and postharvest procedures affect how much weight papayas lose (Nunes *et al*., 2013; Singh & Sudhakar Rao, 2011). Shriveling, a lack of gloss, and a rubbery texture are signs that a fruit is losing weight.

2.13 Edible coating and its effect on the physico-chemical characteristics of *Papaya*

Fruit and vegetables have a layer of waterproof waxes produced by biosynthesis that ranges in thickness when they are in their unprocessed state. Natural waxes slow down plant life processes after harvest, extending the shelf life of plants. They protect the tissue by preventing water losses, controlling gas exchange, guarding against the penetration of harmful elements from the outside environment, and shielding it from harm. The delicate natural wax coatings on fruits and vegetables are damaged during storage and distribution. Fruits and vegetables then lose their quality. (Kitinoja & Kader, 2015). Edible coatings, either in place of or in addition to existing wax, create a semi-permeable membrane on the fruit's surface, preventing respiration, transpiration, ethylene production, and disease incidence (Elsabee & Abdou, 2013).

2.13.1 Effect of edible coatings on firmness of fruits

Fruit and vegetable texture are frequently described in terms of firmness, crispness, juiciness, and toughness. Fresh fruit and vegetable texture is an important quality attribute in consumer acceptance.(Brishti *et al*., 2013). When used in a dry coating process, CMC coatings demonstrated the ability to help retain the original firmness and crispness of apples, berries, peaches, celery, lettuce, and carrots (Huber & Embuscado, 2009). Ergun *et al*. (2006) also found that untreated avocados lost more firmness, whereas wax-treated fruit retained firmness for extended shelf-life. The improved barrier for gaseous and moisture diffusion could explain the increased firmness retention on coated fruit (Tesfay *et al*., 2017).

2.13.2 Weight Loss

Weight loss is a major determinant of *Papaya* fruit storage life and quality (Espitia *et al*., 2012). According to Koushesh Saba and Sogvar (2016), weight loss was lesser in coated *Papaya* fruits than in uncoated *Papaya* fruits. The previous study found up to 21.3% loss in untreated fruits, 18.1% loss in aloe vera, and 12.6% loss in aloe vera combined with ascorbic acid-treated fruits Chitosan was found to maintain the weight of rose apples as a result of increased resistance to water vapour transmission (Plainsirichai *et al*., 2014). High temperatures induced transpiration and respiration processes, which are among the factors that cause water loss from fruit, resulting in weight loss in fruits (Al-Eryani-Raqeeb *et al*., 2009).

2.13.3 Total soluble solids (TSS)

Total soluble solids are associated with fruit sweetness and sometimes used as a criterion in determining maturity (Ngnambala, 2013). The amount of TSS in the fruit increases as it matures and ripens, the soluble solids content of the fruit can be a useful indicator of maturity or stage of ripeness (Ngnambala, 2013). According to Langa (2018), when used to preserve *Papaya* fruit quality for up to 25 and 10 days under cold ambient storage respectively, CMC and chitosan incorporated with moringa had a significant effect on TSS throughout storage.

2.13.4 Titrable acidity TTA, pH

According to Workneh *et al*., (2012), in a modified atmosphere, the fruit's respiration rate decreases, resulting in a decrease in acidity. The TTA content of *Papaya* fruits is significantly affected by storage conditions. TTA values are lower in cold-stored coated fruits due to a slower rate of respiration, which results in slower acid production due to carbohydrate catabolism (Workneh *et al*., 2012). TTA levels in *Papaya* fruits rise, then falls,(Al-Eryani-Raqeeb *et al*., 2009; Singh & Sudhakar Rao, 2011; Workneh *et al*., 2012).Numerous authors; (Singh & Sudhakar Rao, 2011,Bron & Jacomino, 2006; Othman, 2009,Nunes *et al*., 2013) reported a decrease in TTA content during handling irrespective of the temperature regime. pH values decreased in *Papaya* fruits that were stored under ambient storage conditions (Nunes *et al*., 2013).

2.13.5 Vitamin C

Vitamin C (ascorbic acid) is an important component of fruits. In terms of other nutrients, vitamin C content can be used to determine the freshness of fruits and vegetables. Other nutrients may be retained if the vitamin C in the fruit juice is well retained. It is established that vitamin C is extremely heat sensitive. According to Marfil *et al*., (2008), vitamin C is highly susceptible to oxygen therefore, any coating condition that promotes anaerobic atmosphere will result in vitamin C degradation, whereas coating conditions that do not promote aerobic environments will result in vitamin C degradation.

CHAPTER 3

3.0 MATERIALS AND METHOD

3.1 Introduction

The study was conducted in two phases, the first phase was a survey research, while the second phase focused on laboratory investigation.

3.2 Study Area

Phase one was conducted at Nsawam in the Nsawam-Adoagyir District, where data on postharvest handling practices along the *Papaya* value chain were collected. Phase two was conducted at the University of Ghana's Postharvest and Pathology laboratories, where data on physicochemical, pathological and shelf life were gathered.

3.3 Experiment to Achieve Objective 1

3.3.1 Survey Research (Assess the Postharvest Management Practices along the Papaya Value Chain at Nsawam in the Nsawam-Adoagyir District).

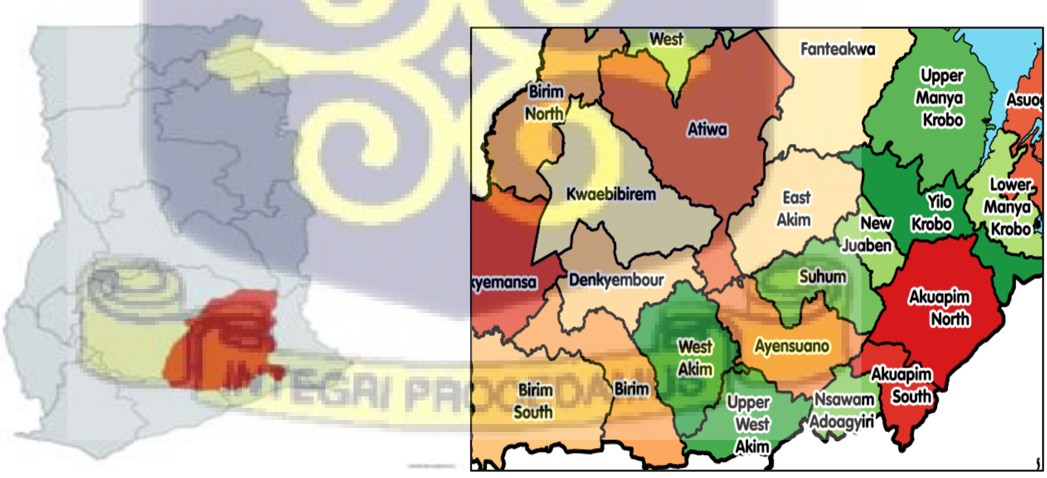

Figure 3.1 Map of Adoagyir in the Nsawam District of the Eastern Region

3.3.2 Sampling Size and Method

Fourty-one (41) producers/farmers and fourty-one (43) traders (transporters, wholesalers, and traders) were interviewed for the study. Purposive sampling was used to select the farmers and dealers. Structured questionnaires (consisting of both close-ended and open-ended questions) as well as field observation, were used to collect data. Field observations were recorded in the form of pictures. Information on demographic characteristics, management practices (harvesting, packaging, storage, and transportation), perception of farmers and traders about edible coating of *Papaya* fruits after harvest, knowledge about post-harvest losses, and causes of these losses and innovations done to reduce losses were collected.

3.4 Experiment to achieve objective 2

3.4.1 Source of Materials used

The solo variety of papaya fruits were obtained from local farmers in the Nsawam area and transported to the postharvest laboratory at the Department of Crop Science in the University of Ghana. Carboxylmethyl cellulose was sourced from India via ubuy.com.gh; (Central Drug House Pvt. Ltd., Mumbai, India). Moringa oil (MO)and neem oil (NO) were sourced locally from Agrimat Agro-chemical shop, Accra, Ghana.

3.4.2Sample Preparation, Application and Storage

Only uniform fruits that were free from pests, diseases, injuries, bruises, and blemishes were chosen in order to maintain the uniformity of the experimental materials.in. The fruits were washed in chlorinated water and wiped with clean disposable tissue towel. Apart from the control, the remaining fruits were treated with coating materials. Fruits were submerged in treatments to coat them and air dried at room temperature. The fruits were placed in various storage conditions. The fruits were kept in the lab at 25 °C, which simulates ambient storage conditions, for 1, 3, 6, 9, 12, and 15 days. The other set of fruits in the same experiment were kept at 10°C under refrigeration temperature (10℃) conditions for 1, 3, 6, 9, 12, 15, 18, 21, 24, and 27 days. About six hundred (600) fruits were utilized.

3.4.3 1% Carboxylmethyl cellulose

1 gram of CMC powder was dissolved in 100 milliliters of distilled water at 75 °C with magnetic stirring for 15 minutes to achieve the 1%CMC coating.

3.4.4 1% Carboxylmethyl cellulose + 1mL moringa oil (CMCMO)

Under continues magnetic stirring 0.5 milliliters (50% v/w) glycerol (based on CMC weight) as plasticizer was added to solubilized 1% CMC and further stirred for 10 min at 70ºC. 1ml of moringa oil and 0.1ml of Tween 80 as emulsifier was measured into a 100ml volumetric flask and topped up with distilled water. The resultant solution was added to the 1% CMC and homogenized at 13,500 rpm for 3 min at 70ºC. The emulsion was cooled to 55ºC and left for a while to exhaust air bubbles constituted during homogenization.

3.4.5 1% Carboxylmethyl cellulose + 3mL moringa oil (CMC3MO)

Under continues magnetic stirring 0.5 mL (50% v/w) glycerol (based on CMC weight) as plasticizer was added to solubilized 1% CMC and further stirred for 10 min at 70ºC. 3ml of moringa oil and 0.3 mL of Tween 80 as emulsifier was measured into a 100ml volumetric flask and topped up with distilled water. The resultant solution was added to the 1% CMC and homogenized at 13,500 rpm for 3 min at 70ºC. The emulsion was cooled to 55ºC and left for a while to exhaust air bubbles constituted during homogenization

3.4.6 1% Carboxylmethyl cellulose + 1ml neem oil (CMCNO)

Under continues magnetic stirring 0.5 milliliters (50% v/w) glycerol (based on CMC weight) as plasticizer was added to solubilized 1% CMC and further stirred for 10 min at 70ºC. 1ml of neem oil and 0.1ml of Tween 80 as emulsifier was measured into a 100ml volumetric flask and topped up with distilled water. The resultant solution was added to the 1% CMC and homogenized at 13,500 rpm for 3 min at 70ºC. The emulsion was cooled to 55ºC and left for a while to exhaust air bubbles constituted during homogenization.

3.4.7 1% Carboxylmethyl cellulose + 3milliliters neem oil (CMC3NO)

Under continues magnetic stirring 0.5 mL (50% v/w) glycerol (based on CMC weight) as plasticizer was added to solubilized 1% CMC and further stirred for 10 min at 70ºC. 3ml of neem oil and 0.3 mL of Tween 80 as emulsifier was measured into a 100ml volumetric flask and topped up with distilled water. The resultant solution was added to the 1% CMC and homogenized at 13,500 rpm for 3 min at 70ºC. The emulsion was cooled to 55ºC and left for a while to exhaust air bubbles constituted during homogenization.

3.4.8 1% Moringa oil (MO)

1ml of moringa oil and 0.1ml of Tween 80 as emulsifier was measured into a 100ml volumetric flask and topped up with distilled water. The resultant solution (1%MO) homogenized at 13,500 rpm for 3 min at 70ºC.

3.4.9 3 % Moringa oil (3MO)

3ml of moringa oil and 0.3ml of Tween 80 as emulsifier was measured into a 100ml volumetric flask and topped up with distilled water. The resultant solution (3%MO) homogenized at 13,500 rpm for 3 min at 70ºC.

3.4.10 1% Neem oil (NO)

1ml of neem oil and 0.1ml of Tween 80 as emulsifier was measured into a 100ml volumetric flask and topped up with distilled water. The resultant solution (1%no) homogenized at 13,500 rpm for 3 min at 70ºC.

3.4.11 3% Neem oil(3NO)

3ml of neem oil and 0.3ml of Tween 80 as emulsifier was measured into a 100ml volumetric flask and topped up with distilled water. The resultant solution (5%no) homogenized at 13,500 rpm for 3 min at 70ºC.

3.5 Experimental design

A 11x2 factorial design set up in completely randomized design (CRD) was carried out with 10 fruits per all treatment and replicated three times.

Table 3.1 Treatments and Ratios

	Treatment	Rates
T1	Control	0
T2	Carboxylmethyl cellulose	1%
T3	Carboxylmethyl cellulose+ Moringa oil	1%:1ml
T4	Carboxylmethyl cellulose+ Moringa oil	1%:3ml
T5	Carboxylmethyl cellulose+ Neem oil	1%:1ml
T6	Carboxylmethyl cellulose+ Neem oil	1%:3ml
T7	Moringa oil extract	1%
T8	Moringa oil extract	3%
T9	Neem oil	1%
T10	Neem oil	3%
T11	Prochloraz (fungicide)	0.3%

3.6 Indices to be measured

The following quality indices were measured: weight loss, firmness, pH, total Soluble Solids (TSS), titratable Acids (TA), vitamin C (Vit. C). and shelf-life studies. In addition to the quality indices, sensory evaluation, isolation and identification pathogens associated with *Papaya* fruit rot, and pathogenicity studies was carried out.

3.6.1 Physiological Loss in weight (PLW)

Using a Bioline Germany electronic scale with two (2) decimal places, the weight of the fruits was measured at the start of the experiment (day 0) and at the end of each storage interval. The following formula was used to calculate weight loss:

$$\text{Weight loss (\%)} = \frac{initial\ weight - final\ weight}{initial\ weight} \times 100$$

3.6.2 Firmness

Fruit firmness was determined destructively with a hand-held penetrometer using the TR Turoni hand-held penetrometer with a 5 mm probe. *Papaya* fruit was randomly selected from each treatment. The plunger of the penetrometer was pushed against the surface of the fruit till it fully penetrates the skin. The maximum force required to puncture the equator region of fruit was recorded. Three different readings were taken from different parts of each fruit and averages computed. Firmness was expressed as Newton(N).

3.6.3 Total soluble solids (TSS)

The fruits were squeezed and the juice tested for TSS using a digital Hanna© refractometer 96801 at room temperature Few drops were placed on the prism of the refractometer to allow for reading measurements. Total soluble solids of the fruits were expressed in Brix

3.6.4 Titratable Acidity:

For the estimation of Titrable acidity, fruits (longitudinal section of fruit was be used) were homogenized and the resultant pulp filtered. Ten (10ml) of the fruit juice was measured into a conical flask and dilute with 50 ml with distilled water. The sample was titrated against 0.1 N NaoH using phenolphthalein as indicator. The result was expressed as % total acid (Titrable Acidity). TA was determined according to the method as described by Ranganna., (1995).

$$\text{Titratable acidity} = \frac{D \times 0.064(\text{NaOH soln is } 0.1N) \times C}{A \times B} \times 100$$

Where, A= Weight of the sample. B= Volume of the sample taken for examination. C=Volume of the sample made with distilled water. D= Burette reading.

3.6.5 pH

The pH of the fruit juice was determined by using a digital Mettler Toledo pH meter. Fruits (longitudinal section of fruit was used) were homogenized and the resultant pulp filtered into a beaker. The glass electrode of the pH meter was inserted into the beaker containing the *Papaya* juice and the pH recorded. The glass electrode was washed with distilled water after each reading.

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3.6.6 Vitamin C Determination

Vitamin C (ascorbic acid) was determined by the titrimetric method according to (AOAC, 1996; AOAC 967.21). Twenty grams of the fruit was blended and the volume made up to 100 ml with 0.4% oxalic acid in a volumetric flask and filtered. 5 ml of the filtrate and 15ml 0.4% oxalic acid was pipetted into a conical flask and titrated with the standard redox dye (2, 6 – dichlorophenol indophenols) in the burette until the solution turned pink and remained at that for colour for 10 seconds. This meant that all the ascorbic acid in the solution had been used up and therefore, there was no electron available to reduce the 2, 6 – dichlorophenol indophenols. The titration reading was calculated by the following formula;

Ascorbic acid (mg/100g) = Titre × Dye equivalent × dilution factor.

3.6.7 Shelf-Life Determination (SL)

The shelf life of stored *Papaya* fruit was calculated by counting the days required for them to reach the final stage of ripening, but only up to the point where they were still marketable.

3.7 Experiment to achieve objective 3

3.7.1 Method for Isolating and Identifying Pathogen Associated with *Papaya* rot

Media Preparation and pathogen isolation

Potato dextrose agar (PDA) was prepared by mixing 39 g PDA with 1 L of water. The PDA was autoclaved for 15 minutes at 121 °C and cooled in a water bath at 40 °C. Small portions of symptomatic tissue from the fruit were isolated and inoculated on petri dishes containing PDA and the dishes was incubated for 7 days at 25 °C. Isolated colonies were sub-cultured on fresh PDA plates until pure cultures are obtained.

3.7.2 Identification of pathogen isolates

The morphological structures were viewed under the light microscope at 40x and 100x magnification. The isolates were identified based on the shape of their spores and the orientation of their hyphae.

3.7.3 Pathogenicity assay

Pure cultures of the isolates were used for pathogenicity test. Symptomless fruits were surface sterilized by washing with 70% ethanol. The fungal mycelium from the pure cultures was cut into small pieces and inoculated on artificially injured healthy fruits. The inoculated wounds were covered with sterilized cotton wool and sealed with a tape. The fruits were stored at room temperature for 7 days. After seven days of inoculation, disease and incidence were verified by observing spore and mycelial of isolates with the light microscope

3.7.4 Decay/rot Percentage

Visual observations were used to determine whether the stored *Papaya* fruit was decaying or rotting. The decay percentage of papaya fruit was calculated by dividing the number of decayed fruits by the total number of fruits multiplied by 100.

3.8 Data Analysis

The data from the laboratory experiments was analyzed using ANOVA in Genstat 12th Edition, and the means were separated using Least Significant Difference (LSD) at 5%. The data collected through questionnaire on postharvest management practices was analyzed using SPSS Version 26 descriptive analysis. Identification of pathogens and pathogenicity of *Papaya* was also described using recommended books.

CHAPTER 4

4.0 Results

4.1. Gender and educational level of respondents

Majority of farmers interviewed were males (83%) and the majority of traders were females (84%). Majority (85.4%) of farmers were educated with the least (2.5%) having tertiary education. Traders on the other hand had (75%) being educated with the least (2.3%) being secondary education and the highest level of education being vocational/technical (4.9%) education.

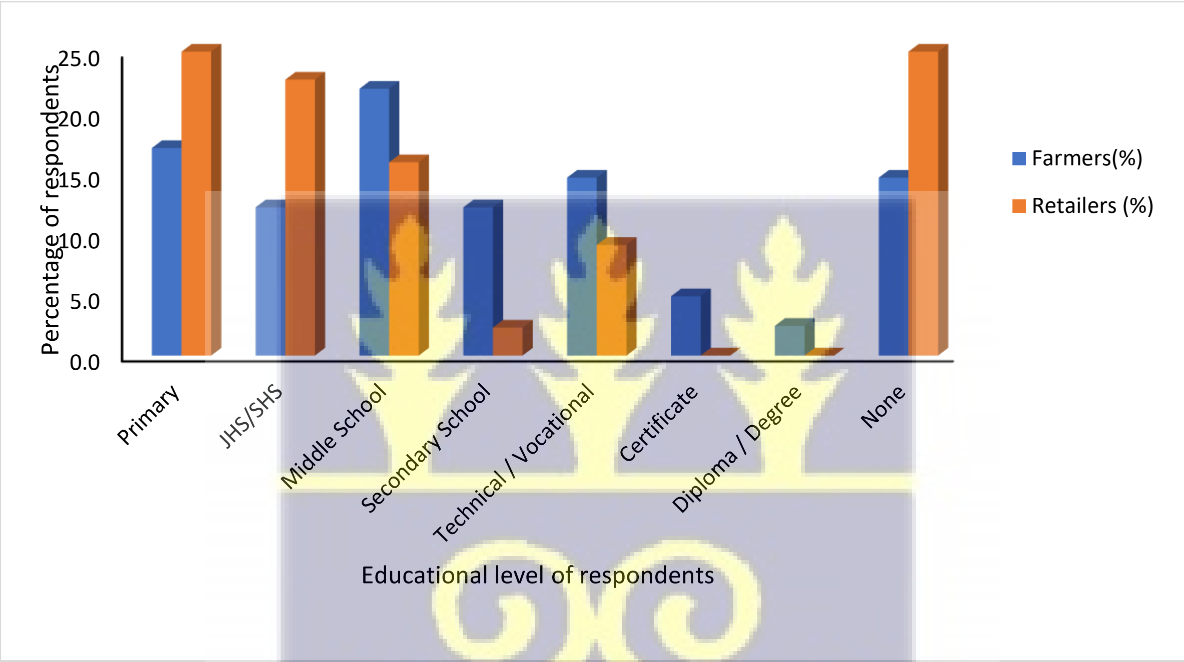

Figure 4.1 Percentage of farmers and traders educational level of respondents

4.2 Pre and Post-Harvest Handling Practices along the *Papaya* value

The value chain of papaya fruits starts from pre-harvest to harvest then postharvest stage. Activities carried out at the various stages influenced the final quality of the fruits.

Field preparation, planting, watering, weed control, insect pests and diseases control were among the pre-harvest activities the farmers employed on their farms. Most (73.2%) of the farmers used their own saved-seeds and cultivated the crop more than twice a year. The study revealed that before harvest, farmers pre-arranged for market. Farmers who failed to find buyers prefer to let their produce rot on the farm. All the farmers harvested their fruits manually. Postharvest activities such as sorting, cleaning, grading, transporting and storing were carried out immediately after harvest. After sorting into various sizes, the farmers had plastic crates that served as the standard for quantifying fruits for sale. Depending on the size of the fruit, the price for a full basket ranged between GHC60 to GHC 100. The fruits were finally transported to various markets for retail. Some of the farmers sold their produce directly to processing companies and exports.

4.2.1 Maturity Stage at Harvest

Half of the farmers harvested their fruits at mature unripe (green) (51.2%), half ripe (42%) and yellow ripe (7%).

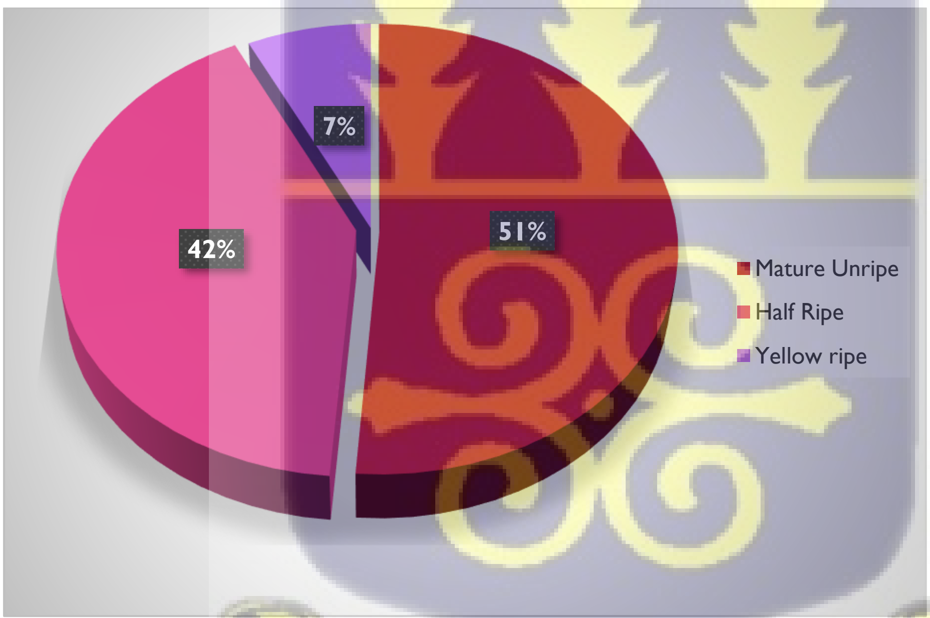

Figure 4.2 Percentage of maturity stages at harvest

4.2.2 Packaging Material

Most of the farmers used shallow wooden boxes (37%), plastic crates (24.4%), cane or deep wooden boxes (19.5%) to carry harvested *Papaya* fruits on their farms.

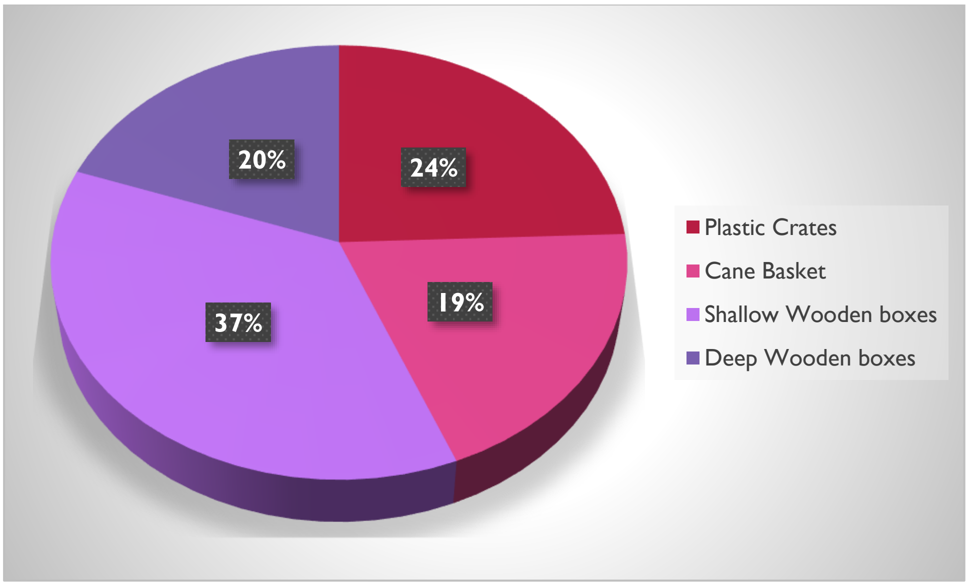

Figure 4.3 Percentage of Packaging containers used by farmers

4.2.3 Transportation

4.2.3.1 Vehicle type and cover material during transport

Majority (81.8%) of the traders used vehicles to convey the *Papaya* fruits whiles, (18.2%) used. For the traders who used vehicles, 50%, used roofed and (31.8%) open trucks. The majority of traders (68.2%) do not cover the fruits during transportation, 11.4%, 2.3 traders, used cloth or tarpaulin and polythene sheets respectively. From the results, it was observed that majority of traders (62.8%) do not cover the purchased fruits during transportation and others used cloth or tarpaulin (11.4%) or polythene sheets (2.3%)

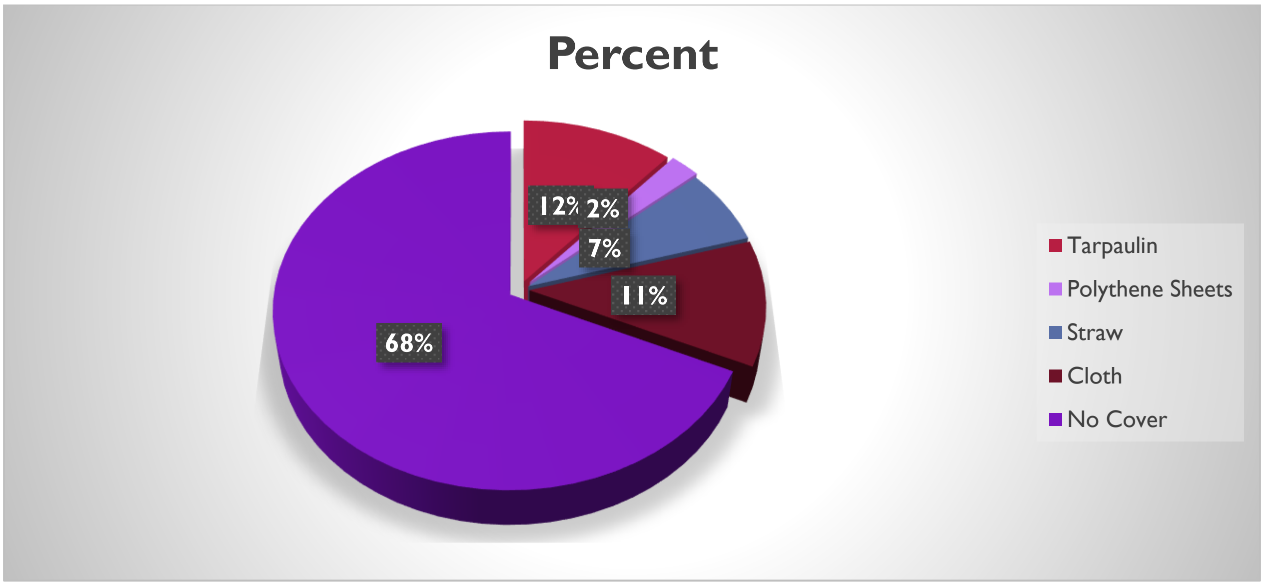

Figure 4.4 Percentage of covering materials used during transportation

4.2.4 Storage Practices

4.2.4.1 Fruits storage environment and challenges by traders

From this survey, it was observed that majority (91%) of the traders placed the fruits in a storage container whiles, (9%) placed them on a cemented floor in the market/point of sale (77%) or at home (23%) where fruits are stored. The major challenge faced by traders were rot (61.4%). and attack by rodents (36.6%).

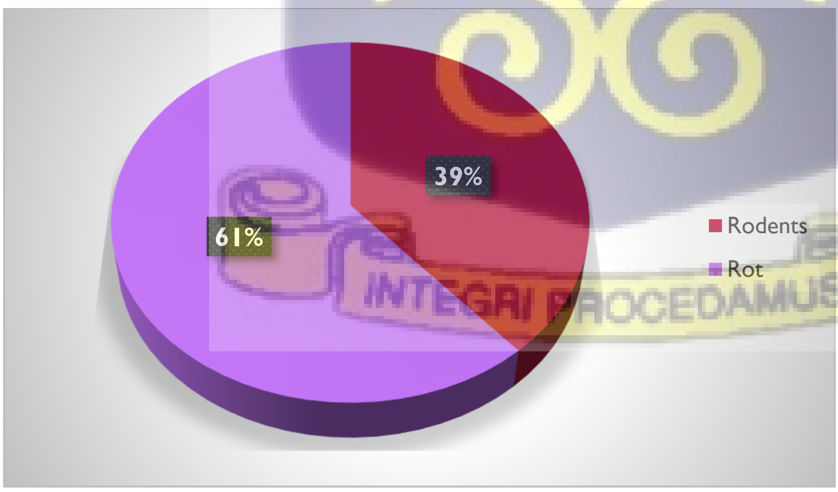

Figure 4.5 Percentage of traders and their storage challenges traders

4.2.5.0 Post-Harvest Losses

4.2.5.1 Types of Losses Incurred during Harvesting and Packaging

The types of losses incurred during harvesting and packaging were categorized into mechanical, physiological and rot. Mechanical losses at harvesting and packaging were 68.3% and 80.5%, respectively. For the physiological losses, 24.4% occurred at harvest whiles 4.9% occurred at packaging. Whiles losses due to fruit rot was 2.4% at harvest and 4.9% of the famers did not incur any loss at harvest.

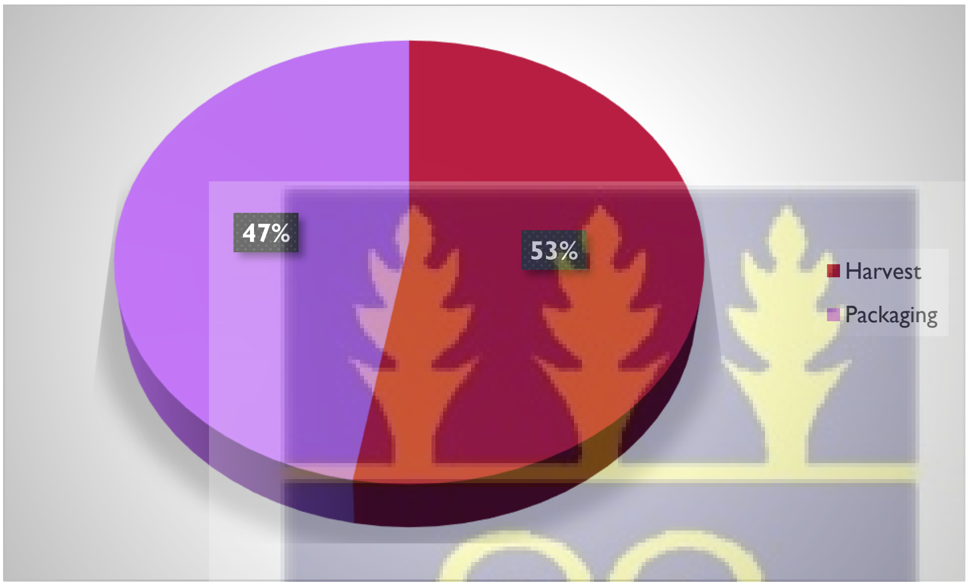

Figure 4.6 Percentage of losses Incurred during Harvesting and Packaging

4.2.5.2 Stage of most Losses Occurred

More than half (65.9%) of the farmers acknowledged that most losses occurred at harvest, 29.3% during sale and 2.4% whiles loading. On the part of traders, 52.3%, said most losses occurred during storage, sale 38.6%, and during transport 4.8%.

4.2.5.3 Estimate of losses Along the *Papaya* Value Chain

On an acre of land, the farmers' financial losses from *Papaya* fruits at harvest ranged from 60-300 Ghana cedis (GHC) out of an estimated income of one thousand (1000) GHC. Most

(68.3%) farmers lost G HC 240 at harvest, 17.1% lost GHC 420, 9.8% lost GHC 660 with 2.4% incurring no losses at harvest. More than half (75.6%) of the farmers estimated their losses due to packaging as GHC 120, 9.8% of them estimated their losses as GHC 300 whiles, 14.6% did not incur losses at packaging. The highest estimate of financial losses occurred at the harvesting stage of the fruits. On the purchase of 500 cedis worth of *Papaya* fruits, the estimate of losses incurred by the traders ranged from GHC 50 and GHC 150. Thirty percent (30%) of the traders reported having incurred a loss of GHC 50 whiles 68% of them incurred a loss of GHC 100. The remaining 2% of the traders interviewed lost an amount of GHC 150 due to the fruit losses

4.2.6 Respondents Knowledge on Coating Materials, Modern Post-Harvest Technology and Willingness to Adopt Innovative Post-Harvest Technology

Most (92.5%) of farmers had no knowledge of coating and modern storage technology (90.2%) technology. Majority (87.8) of these farmers were also not open to the idea of adopting modern postharvest technology but 12.2% were ready to adopt this modern storage technology.

Majority (75%) of traders also did not have any knowledge of coating However, all traders were open to adopting the use of modern post-harvest technology in the storage and sale of their fruits. With regards to the use of coating materials on fruits, all the respondents (both farmers and traders) did not use any coating.

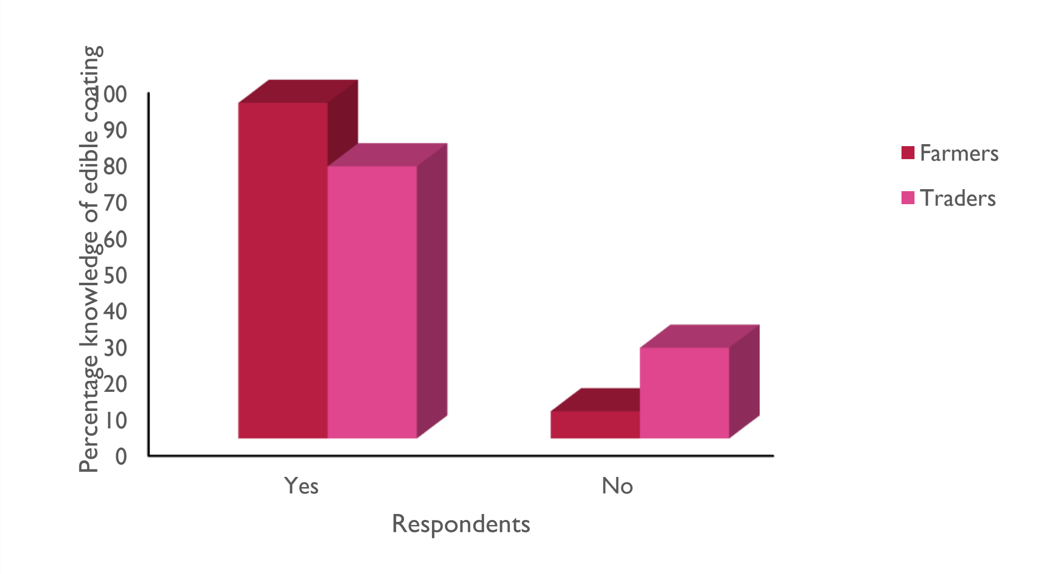

Figure 4.7 Percentage knowledge of coating by respondents

4.2.7 Services from Agricultural Extension Agents (AEAs)

Most farmers (75%) responded in the negative to having access to extension agents whiles 24% of them responded in the affirmative to having access to extension agents. Some of the services included;

- Training in the correct use of agro-chemicals, troubleshooting of farm implements
- Provision of seeds
- Other advisory services

4.2.8 Shelf life

Comparatively, fruits in refrigeration temperature (10℃) had prolonged shelf life (21 days) than fruits stored at ambient temperature (9 days). In refrigeration temperature (10℃) (10℃ / 67% rh), fruits coated with 1%CMC, 1%CMCNO and 0.3% Pro prolonged fruit life up to 27 days.

Similarly, in ambient storage, fruits coated with 1%CMC, 1%CMCNO and 0.3% Pro also had extended shelf life up to 15.

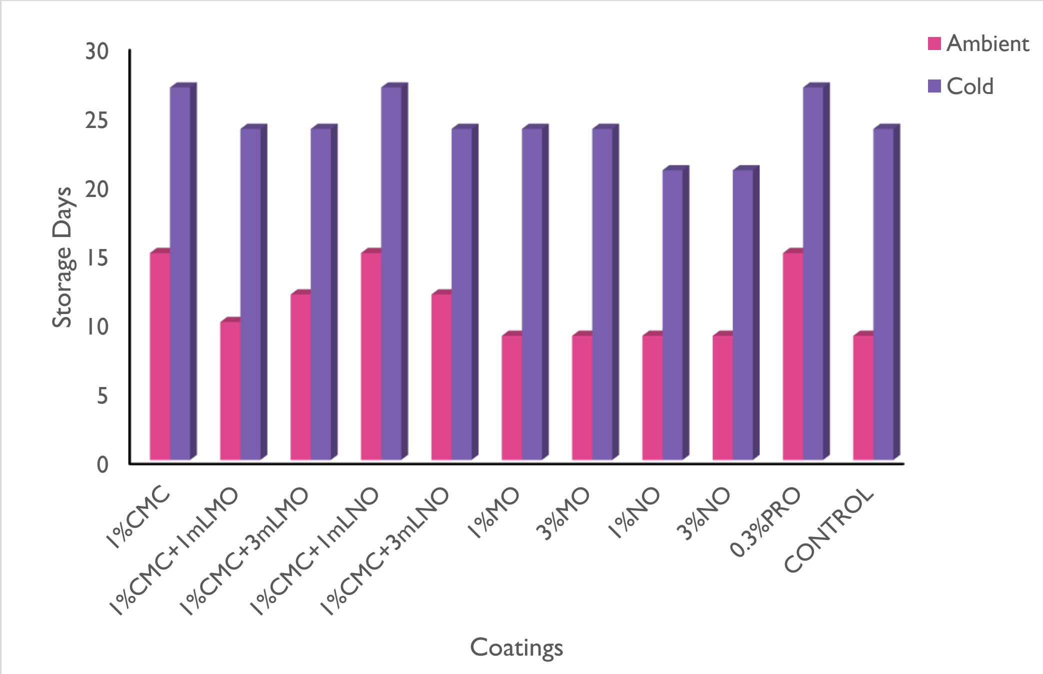

Figure 4.8 Maximum days of coated fruits at ambient (27) and refrigeration temperature (10°C)

4.2.9 Effect of coatings on percentage weight loss of papaya fruits stored for 15 days at ambient (27°C) and refrigeration (10°C) temperatures

Generally, there was a significant ($p<0.05$) increase in weight loss as days of storage increased with both storage temperatures (Table 4.1). There was a significant interaction ($p<0.05$) between the coatings and the storage conditions. However, refrigerated fruits (10°C) had lower weight losses as compared with fruits store at room temperature (27°C) and they as well stored longer, up to 15 days. Coated fruits had significantly ($p<0.05$) lower weight losses compared with the uncoated control in both storage conditions.

In the ambient condition, edible coatings 1%CMC and 1%CMCNO reduced weight loss in the papaya fruits as well as 0.3%PRO (the fungicide) ($p>0.05$) did for 15 days but not as well in refrigerated conditions ($p<0.05$) (Table 4.1)

Table 4.1 Percentage weight loss of papaya fruits after coating and stored for up to 15 days of storage in ambient (27°C) and refrigeration (10°C) temperature

Storage Condition	Coatings	3	6	9	12	15	Mean (Coating)
		Days of storage					
			Weight Loss (%)				
Ambient	1%CMC	3.69	6.64	8.85	12.2	13.47	8.97
	1%CMCMO	4.28	9.17	13.34	*	*	8.93
	1%CMC3MO	6.18	8.67	11.55	*	*	7.43
	1%CMCNO	3.60	6.58	10.79	12.52	12.28	9.16
	1%CMC3NO	4.11	7.51	12.79	*	*	8.14
	1%MO	2.81	6.28	9.58	*	*	6.22
	3%MO	4.70	6.86	7.19	*	*	6.25
	1%NO	5.27	11.16	10.27	*	*	8.90
	3%NO	4.20	7.59	8.39	*	*	5.90
	3%PRO	2.61	5.76	8.85	12.28	12.00	8.30
	CTRL	5.74	11.89	15.34	*	*	10.9
Cold	1%CMC	1.30	2.35	3.46	4.01	4.38	4.39
	1%CMCMO	1.68	2.22	2.90	3.47	3.51	4.55
	1%CMC3MO	1.07	1.49	2.27	2.833	3.07	4.65
	1%CMCNO	1.93	3.10	3.92	3.81	4.63	4.83
	1%CMC3NO	1.88	2.82	3.99	5.40	5.99	4.85
	1%MO	1.25	2.27	2.22	2.29	2.85	4.69
	3%MO	1.05	1.74	2.08	2.23	2.42	4.99
	1%NO	1.26	1.94	3.06	3.36	4.79	5.51
	3%NO	1.27	2.02	2.79	3.68	4.87	5.69
	3%PRO	0.75	1.37	1.86	2.19	2.23	1.68
	CTRL	2.75	4.43	5.38	7.66	9.51	7.83
	Mean	2.89	5.18	5.57	6.14	6.86	

LSD (0.05) Coating=0.50 Storage Cond.=0.32 Coating * Storage Cond =1.60

*Fruit decay

4.2.10 Effect of coatings on firmness of papaya fruits stored up to 15 days in ambient (27°C) and refrigeration (10°C) temperatures

Firmness of papaya fruits decreased in all storage temperature conditions as storage days increased (Table 4). However, the analysis showed a significant interaction ($p<0.05$) between the two factors, namely, coating and storage condition. Firmness of the papaya fruits stored in ambient temperature decreased by up to 71.5% on the 15th day while in cold storage fruit firmness reduced by only 33.7% during the same period.

Irrespective of the storage condition, papaya fruits coated that stored up to 15 days (1%CMC and 1%CMCNO) significantly compared ($p>0.05$) in fruit firmness with the fungicide treated papaya fruits (0.3%PRO).

Table 4.2 Firmness of papaya fruits following coating and storage for up to 15 days at stored in ambient (27°C) and refrigeration (10°C) temperatures)

*Fruit decay

Storage Condition		Days of storage 1	3	6 Firmness (N)	9	12	15	Mean Coating
Ambient	1%CMC	18.27	15.86	11.86	8.93	6.64	4.86	11.07
	1%CMCMO	18.27	14.21	7.82	4.72	*	*	11.26
	1%CMC3MO	18.27	15.92	12.3	8.44	*	*	13.73
	1%CMCNO	18.27	15.13	12.02	10.0	8.01	4.85	11.38
	1%CMC3NO	18.27	13.45	9.58	4.27	*	*	11.39
	1%MO	18.27	13.47	6.53	6.97	*	*	11.31
	3%MO	18.27	13.54	8.65	5.77	*	*	11.56
	1%NO	18.27	11.03	6.22	4.5			10.01
	3%NO	18.27	11.88	3.57	3.6	*	*	9.33
	3%PRO	18.27	15.44	13.05	10.28	7.05	5.21	11.55
	CTRL	18.27	9.29	4.55	2.17	*	*	8.57
Cold	1%CMC	18.27	16.6	15.13	14.46	13.54	12.52	15.09
	1%CMCMO	18.27	15.87	15.12	13.76	12.66	10.15	14.31
	1%CMC3MO	18.27	16.85	15.82	14.85	12.79	11.51	15.02
	1%CMCNO	18.27	17.32	15.63	14.9	12.94	11.86	15.15
	1%CMC3NO	18.27	14.43	15.81	13.11	12.92	13.04	14.60
	1%MO	18.27	16.84	13.46	13.14	12.99	12.65	14.56
	3%MO	18.27	16.57	15.03	14.58	14.45	14.31	15.54
	1%NO	18.27	14.42	13.97	13.17	12.42	13.03	14.21
	3%NO	18.27	15.59	14.02	13.7	13.54	13.52	14.77
	3%PRO	18.27	17.08	15.4	14.94	13.42	12.12	15.21
	CTRL	18.27	13.46	12.69	11.29	9.71	7.12	12.09
	Mean	18.27	14.37	11.387	11.27	11.05	10.06	

LSD's (0.05) Coating=2.0 Storage condition=1.50 Coating*storage condition=6.0

4.2.11Effect of coatings on Total soluble solids TSS (Brix) of papaya fruits stored in ambient (27°C) and refrigeration (10°C) temperatures

Generally, the TSS of the papaya fruits increased to highest on the 9th day and decreased till end of experiment on 15th day, except for those that deteriorated (Table 4.3). Coatings impregnated with MO and NO had higher TSS (Brix) means compared to those without. Cold storage conditions had a lesser effect on TSS (Brix) compared with ambient storage, although it extended the duration of storage. The control group had significantly higher TSS (Brix) means ($p<0.05$) compared to most of the coatings for both storage conditions. The effect of coatings on TSS (Brix) was more significant ($p<0.05$) than that of storage conditions, and the effect of their interaction was moderate.

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Table 4.3 TSS (Brix) of papaya fruits following application of coating stored for 15 days in ambient (27°C) and refrigeration (10°C) temperatures

Storage Condition	Days of storage							Mean (Coating)
		1	3	6	9	12	15	
	Coatings			TSS(Brix)				
Ambient	1%CMC	7.20	8.04	10.27	10.43	9.78	9.90	9.27
	1%CMCMO	7.20	10.57	11.27	10.75	*	*	9.95
	1%CMC3MO	7.20	9.77	11.40	12.15	*	*	9.46
	1%CMCNO	7.20	9.70	10.43	10.50	9.78	9.20	9.47
	1%CMC3NO	7.20	8.43	10.40	11.00	*	*	9.26
	1%MO	7.20	11.32	10.73	10.60	*	*	9.96
	3%MO	7.20	11.23	6.55	9.80	*	*	8.70
	1%NO	7.20	11.78	11.80	11.05	*	*	10.46
	3%NO	7.20	10.18	10.7	11.63	*	*	9.36
	3%PRO	7.20	11.25	10.25	11.60	11.30	8.20	9.97
	CTRL	7.20	10.76	12.97	13.43	*	*	11.09
Cold	1%CMC	7.20	8.80	10.30	10.41	9.97	9.97	9.43
	1%CMCMO	7.20	9.98	9.67	9.83	10.63	10.13	9.57
	1%CMC3MO	7.20	9.77	9.06	9.80	9.03	9.53	9.07
	1%CMCNO	7.20	9.96	10.17	10.70	10.20	9.70	9.66
	1%CMC3NO	7.20	11.04	9.17	10.23	10.60	9.73	9.66
	1%MO	7.20	10.82	10.55	10.70	10.50	10.45	10.04
	3%MO	7.20	10.35	9.70	11.40	8.20	10.90	9.63
	1%NO	7.20	10.58	10.85	10.80	10.35	9.70	9.91
	3%NO	7.20	10.25	9.70	10.40	10.50	10.20	9.71
	3%PRO	7.20	9.15	8.10	10.60	10.90	10.05	9.33
	CTRL	7.20	10.36	9.70	10.67	10.47	10.73	9.86
Mean (Storage condition)		7.20	10.26	10.10	10.73	10.15	9.89	
LSD's (0.05)	Coatings=0.56		Storage condition=0.36		Coating*storage condition=1.30			

*Fruit decay

4.2.12 Effect of coatings and storage condition on Vitamin C content of on papaya fruits stored in ambient and refrigeration temperature (10°C) condition

Vitamin C increased significantly ($p<0.05$) as days increased (Table 4.4). The results of the analysis showed that there was a significant interaction ($p<0.05$) between the two factors on the vitamin C content. The difference in means between the different coatings and storage conditions ranged from 2.71 to 5.75 mg/mL for the ambient storage condition and 2.71 to 5.29 mg/mL for the cold storage condition.

Coated fruits had significantly ($p<0.05$) higher vitamin C content compared with uncoated control. In ambient temperature., CMCNO and CMC3NO had significantly higher Vitamin C content ($p<0.05$) than coatings containing PRO. The mean Vitamin C content under cold storage conditions was higher than that under ambient storage conditions. There was a significant interaction in vitamins C content between coating and storage condition (Table 4.7). In refrigeration temperature (10°C), 1%CMC3MO had significantly higher (4.44mg/mL) vitamin C content ($p<0.05$) compared with the control, with the lowest (3.04mg/mL) vitamin C content.

Table 4.4 Vitamin C content of papaya fruits after coatings and stored for up to 15 days in ambient and refrigeration temperature (10°C)

Storage condition	Days of storage	1	3	6	9	12	15	Mean (Coating)
				Vit. C mg/ml				
	Coatings							
Ambient	1%CMC	2.71	3.37	4.03	4.38	5.14	5.75	4.23
	1%CMCMO	2.71	3.64	4.98	5.66	*	*	4.25
	1%CMC3MO	2.71	3.87	5.29	5.29	*	*	3.96
	1%CMCNO	2.71	3.55	4.55	4.73	5.99	5.57	4.52
	1%CMC3NO	2.71	3.71	4.87	5.51	*	*	4.20
	1%MO	2.71	3.64	4.11	4.45	*	*	3.73
	3%MO	2.71	3.79	4.32	4.85	*	*	3.92
	1%NO	2.71	3.71	3.92	4.26	*	*	3.65
	3%NO	2.71	3.57	3.67	4.54	*	*	3.32
	3%PRO	2.71	2.97	3.68	4.04	3.77	*3.32	3.43
	CTRL	2.71	2.76	2.53	3.06	*	*	2.77
Cold	1%CMC	2.714	3.27	3.36	4.11	4.50	5.12	3.85
	1%CMCMO	2.71	3.79	3.95	4.49	5.02	5.19	4.19
	1%CMC3MO	2.71	4.06	4.50	4.95	5.24	5.19	4.44
	1%CMCNO	2.71	3.60	3.86	4.57	5.10	5.24	4.18
	1%CMC3NO	2.71	3.33	4.11	4.31	5.17	5.29	4.15
	1%MO	2.71	3.62	3.75	3.39	5.25	5.00	3.95
	3%MO	2.71	3.53	3.57	3.14	5.25	4.96	3.86
	1%NO	2.71	3.47	3.54	3.29	5.1	5.00	3.85
	3%NO	2.71	3.43	3.44	3.50	3.19	5.25	3.59
	3%PRO	2.71	3.11	3.36	3.32	5.11	2.79	3.40
	CTRL	2.71	2.95	3.01	3.21	3.19	3.17	3.04
Mean (Storage condition)		2.71	3.49	3.93	4.16	4.76	4.92	
LSD's (0.05)	Coatings=0.1			Coating*Storage condition=0.23				

*Fruit decay

4..2.13 Effect of coatings on pH of papaya fruits stored up to 15 days in ambient temperature (27°C) and refrigeration (10°C) temperatures

Generally, coatings and storage temperatures had significant effect ($p<0.05$) on pH of *Papaya* fruits). Furthermore, significant interaction effect was observed among coatings (Appendix 4) In ambient temperature Significant differences ($p<0.05$) were observed between the pH of coated and uncoated fruits. Treatment, 1%CMC3NO coated fruits had significantly ($p<0.05$) the highest (5.90) pH compared to the control with the least (4.88)

Table 4.5 pH following coatings on pH of papaya fruits stored up to 15 days in ambient and refrigeration temperature (10°C)

*Fruit decay

Storage condition	Coatings	Days of storage 1	3	6	9	12	15	Mean (Coating)
Ambient	1%CMC	5.29	5.34	5.4	5.76	5.34	5.14	5.38
	1%CMCMO	5.29	5.45	5.35	5.67	*	*	5.44
	1%CMC3MO	5.29	5.59	5.59	5.72	*	*	5.53
	1%CMCNO	5.29	5.28	5.4	5.45	5.34	5.25	5.33
	1%CMC3NO	5.29	5.31	5.45	5.88	*	*	5.48
	1%MO	5.29	5.27	5.39	5.527	*	*	5.37
	3%MO	5.29	5.43	5.28	5.42	*	*	5.35
	1%NO	5.29	5.23	5.31	5.52	*	*	5.36
	3%NO	5.29	5.42	5.42	5.42	*	*	5.38
	3%PRO	5.29	5.3	5.33	5.73	5.33	5.29	5.36
	CTRL	5.29	5.25	4.25	5.63	*	*	5.11
Cold	1%CMC	5.29	5.19	5.24	5.35	5.53	5.57	5.56
	1%CMCMO	5.29	5.3	5.13	5.41	5.52	5.66	5.6
	1%CMC3MO	5.29	5.73	5.06	5.48	5.29	5.42	5.6
	1%CMCNO	5.29	5.13	5.28	5.37	5.59	5.58	5.52
	1%CMC3NO	5.29	5.2	5.37	5.43	5.52	5.31	5.9
	1%MO	5.29	5.08	5.11	5.33	5.62	5.61	5.5
	3%MO	5.29	5.12	5.18	5.53	5.57	5.47	5.51
	1%NO	5.29	4.96	5.33	5.4	5.56	5.63	5.6
	3%NO	5.29	4.96	5.18	5.45	5.56	5.63	5.58
	3%PRO	5.29	5.03	5.41	5.5	5.32	5.58	5.6
	CTRL	5.29	4.47	5.37	5.2	4.28	4.67	4.88
Mean (Storage condition)		5.29	5.23	5.27	5.51	5.38	5.42	
LSD's (0.05)	Coatings=0.142	Storage condition=0.01	Coating*storage condition=0.34					

4.2.14 Effect of coatings on TTA of papaya fruits stored up to 15 days in ambient (27°C) and refrigeration (10°C) temperatures conditions

There was significant increase($p<0.05$) in titrable acidity from day 1 (0.03 malic acid) to the 6^{th} day (0.23) but declined on day 9 (0.20) (Table 4.6). There were significant differences ($p<0.05$) between coated and uncoated fruits.

In ambient storage, control fruits had lower (0.09 malic acid) from 1%CMC coated fruits with a high (0.11 malic acid) TTA. 3MO recorded the highest (1.3) on day 6 throughout storage, but the difference was not statistically significant ($p>0.05$).

In refrigeration temperature (10°C) control had the least (0.10malic acid) significantly different ($p<0.05$) from 1%CMC coated fruits with the highest (0.36) TTA. In addition, 1%CMC also recorded the highest (1.55 malic acid) on day 6.

Table 4.6 TTA after coating of papaya fruits stored up to 15 days in ambient (27°C) and refrigeration (10°C) temperatures

*Fruit decayed

Storage condition		Days of storage						Means (Coating)
		0	3	6	9	12	15	
	Coatings	TTA						
Ambient	1%CMC	0.03	0.2	0.32	0.17	0.04	0.05	0.14
	1%CMCMO	0.03	0.2	0.19	0.07	*	*	0.12
	1%CMC3MO	0.03	0.21	0.18	0.16	*	*	0.14
	1%CMCNO	0.03	0.16	0.22	0.09	0.07	0.06	0.11
	1%CMC3NO	0.03	0.22	0.27	0.06	*	*	0.15
	1%MO	0.03	0.32	0.29	0.11	*	*	0.19
	3%MO	0.03	0.27	1.3	0.08	*	*	0.4 2
	1%NO	0.03	0.13	0.2	0.16	*	*	0.13
	3%NO	0.03	0.22	0.13	0.11	*	*	0.12
	3%PRO	0.03	0.12	0.11	0.16	0.08	0.13	0.10
	CTRL	0.03	0.11	0.12	0.11	*	*	0.09
Cold	1%CMC	0.03	0.12	1.55	0.24	0.14	0.06	0.36
	1%CMCMO	0.03	0.17	0.05	0.26	0.13	0.04	0.12
	1%CMC3MO	0.03	0.52	0.07	0.26	0.18	0.06	0.19
	1%CMCNO	0.03	0.15	0.06	0.26	0.14	0.04	0.11
	1%CMC3NO	0.03	0.2	0.05	0.26	0.16	0.05	0.12
	1%MO	0.03	0.16	0.05	0.27	0.16	0.06	0.12
	3%MO	0.03	0.06	0.06	0.29	0.16	0.05	0.11
	1%NO	0.03	1.14	0.06	0.29	0.17	0.04	0.29
	3%NO	0.03	0.21	0.05	0.25	0.16	0.05	0.13
	3%PRO	0.03	0.21	0.21	0.26	0.15	0.06	0.15
	CTRL	0.03	0.05	0.07	0.25	0.15	0.04	0.10
	Means (Storage condition)	0.03	0.23	0.28	0.2	0.1 4	0.06	

LSD's (0.05) Coatings= 0.20 Storage condition= 0.13 Coating*storage condition= 0.46

4.2.9. Nature of pathogens isolated after coating and in ambient and refrigeration temperature storage conditions

Nine (9) fungal species were isolated and identified from papaya (Table 4.7). Six fungal isolates from ambient (26.8°C/76.7% rh) and three (3) from cold (10.1°C/68.2% rh) storage (Table 4.8). *Fusarium* spp., *C. gloeosporiodes and L. theobromae* was common in both storages. *Fusarium* spp. isolates were high in both storage conditions.

Generally, fruits stored in ambient temperature showed disease symptoms on the control fruits after six (6) days whiles, treated fruits showed disease symptoms after twelve (12) days. Whiles, disease symptoms showed later in cold storage; twelve (12) days for the control and fifteen (15) days for coated fruits. Pathogens were identified with their cultural and morphological characteristics:

After 3 days of innoculation, *Aspergilus flavus* colonies grew fast with powdery green colour colonies almost covering the plate. Aseptate hyphae bearing spherical conidia from thick-walled foot cells (Plate 4.2)

Colonies of C. gloeosporioides were initially white, but grey as the culture aged. In 9 days, Hyphae grew to fill the entire 9 mm Petri dish. In culture, the isolates produced bright orange acervuli with numerous spores (conidia). The spores were short, conical, with rounded edges. (Plate 4.3).

Fusarium sp. colonies grew quickly, reaching 4.5 cm in four days. When sporodochia evolved, mycelium was white to cream, almost orange-brown. After 4-7 days, macroconidia formed from short multiple septate conidiophores that formed the sporodochia. They were three to five septate, fusiform, cylindrical, and curved moderately (Plate 4.4).

Lasiodiplodia theobromae isolates produced white mycelium that turned black as the culture aged. In 5 days, mycelia grew to fill the entire 9 mm plate. The hyphae were initially hyaline, then darkened and septated. After 14 days, mature uniseptate, brown, ovoid conidia were observed. (Plate 4.5).

Penicillium spp. colonies were also fast growing, consisting of a green dense conidiophores. Microscopically, chains of single-celled conidia were observed in basipetal succession from a phialide (Plate 4.6.).

Unidentified *Fante kenkey-like* fungus isolates grew virulently, myecellium filled and grew out of petri dish . It produced orange myecellium. Hyphae was aseptate and without conidia (Plate 4.7).

Table 4.7 Pathogens identified on fruits stored in ambient (27°C) temperature

Coatings	Pathogens
Control	*Lasiodiplodia theobromae, Colletotrichum gloeosporoides, Fusarium* spp.**Fante kenkey-like*
1%CMC	*fungus**
1%CMC+ImLMO	*Fusarium* spp.
1%CMC+3mLMO	*Fusarium* spp.
1%CMC+1mLNO	*Aspergillus flavus*
1%CMC+3mLNO	*Fusarium* spp.
1%NO	*Aspergillus niger*
3%NO	*Fusarium*
1%MO	*Penicillium, Aspergillus niger*
3%MO	*Colletotrichum gloeosporoides*
0.3%Prochloraz	*Fusarium, Aspergillus niger*
	Aspergillus flavus, *Fante kenkey like fungus*(unidentified)

Table 4.8 Pathogens identified on fruits in refrigeration temperature (10°C)

Coatings	Pathogens
Control	*Fusarium, Lasiodiplodia theobromae, Colletotrichum gloeosporoides*
1%Carboxylmethyl Cellulose	*Fusarium*
1%CMC+ImLMO	*Fusarium*
1%CMC+3mLMO	*Colletotrichum*
1%CMC+1mLNO	*Fusarium*
1%CMC+3mLNO	*Fusarium*
1%NO	*Fusarium*
3%NO	*Fusarium*
1%MO	*Colletotrichum gloeosporiodes*
3%MO	*Fusarium*
0.3%Prochloraz	*Fusarium*

4.2.9.3 Effect of coatings on the frequency of pathogens stored in ambient and refrigeration temperature (10°C)

Fusarium spp. rot was the highest among treatments. A frequency of 54% and 81.2 % in ambient and cold storage respectively. *Penicillium* spp. *(9.1%)* and *Lasiodiplodia (9.1%)* were the least in ambient and *Lasiodiplodia* (9.1) was the least isolate in cold storage (Fig. 4.14)).

An unidentified fungus was isolated similar to a fungus found on a popular dense maize food peculiar to an ethnic group in Ghana called, Fante kenkey like. *Penicillium, Aspergillus flavus,* unidentified fungus were only isolated from fruits in ambient storage.

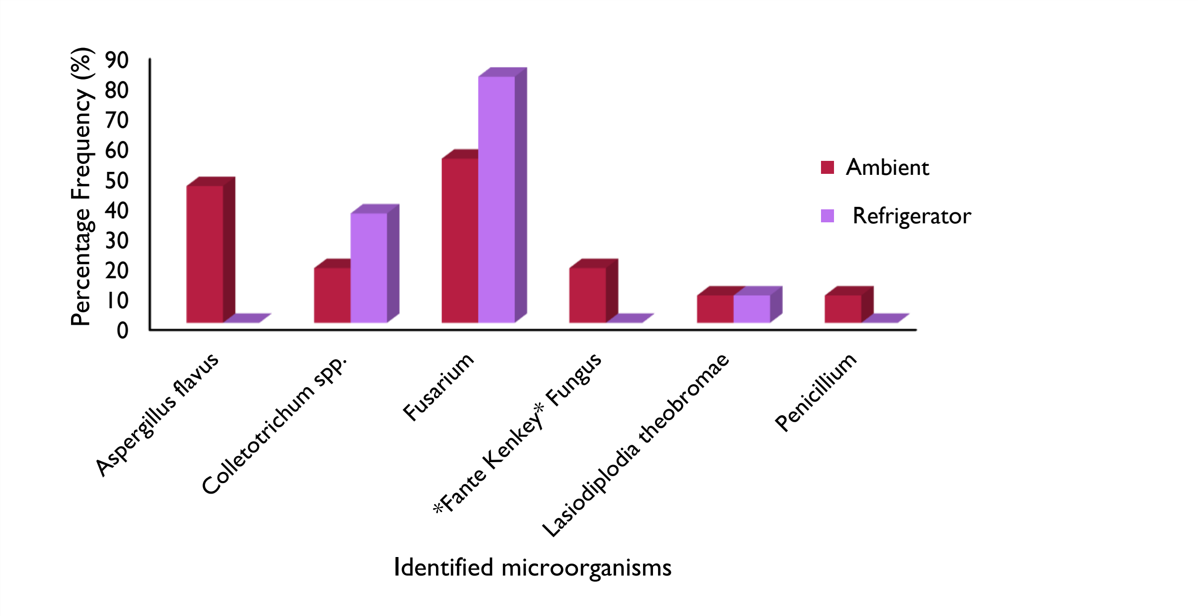

Figure 4.9 Fig. 4.14 Percentage frequency of fungi identified in ambient (27°C/77%rh) and refrigeration temperature (10°C/67%rh)

4.2.9.11Effect of coatings on disease incidence of *Papaya in* ambient (27°C/78%rh) and refrigeration (10°C/67%rh)

Coatings had significant ($p<0.05$) effect on *Papaya* in both storage temperatures (Table 4.11). Coated fruits had lower disease incidence compared to uncoated fruits. For coatings in ambient storage the least significantly different ($p<0.05$) disease incidence (36.67%) was observed in 0.3%Pro coated fruits compared to the control with the highest incidence (76.67%). On the other hand, in refrigeration temperature, fruits coated with 1%CMCNO had the least (23.33%) disease incidence compared to the control with the highest (76.67%) disease incidence. Disease incidence of coatings in ambient temperature were significantly ($p<0.05$) higher than those in refrigeration temperature (10°C).

Table 4.9 Incidence of papaya pathogens on fruits in ambient (27°C/77rh) and refrigeration temperature (10°C/67rh)

Means followed by different letters are significantly different at ($p<0.05$)

Treatments	Ambient	Cold	Means
1%CMC	63.33g	33.33abcd	48.33b
1%CMC+1mLMO	43.33def	30abc	36.67cd
1%CMC+3mLMO	46.67ef	30abc	38.33cd
1%CMC+1mLNO	43.33def	23.33a	33.33d
1%CMC+3mLNO	40cdef	26.67ab	33.33d
1%MO	50f	33.33abcd	41.67bc
3%MO	43.33def	33.33abcd	38.33cd
1%NO	40cdef	30abc	35cd
3%NO	46.67ef	33.33abcd	38.33cd
0.0.3%Pro	36.67bcde	36.67bcde	36.67d
Control	76.67h	46.67ef	61.68a

Plate 4.1 Papaya fruits showing disease symptoms

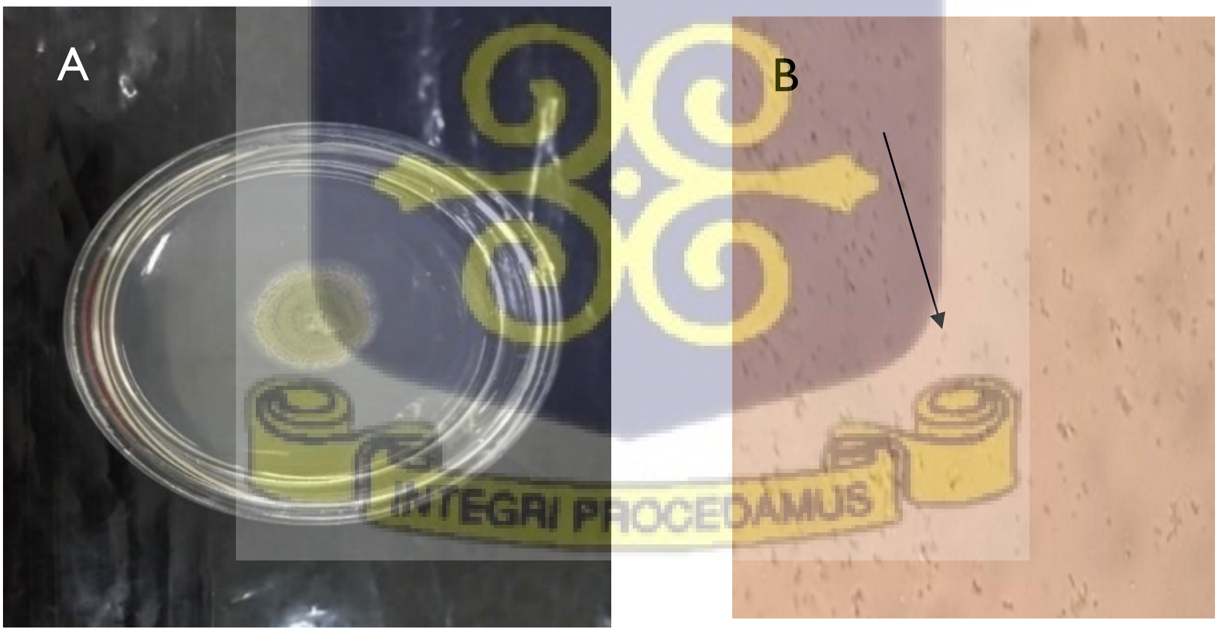

Plate 4.2.Culture (A) and micrograph (B) of *Aspergillus flavus*

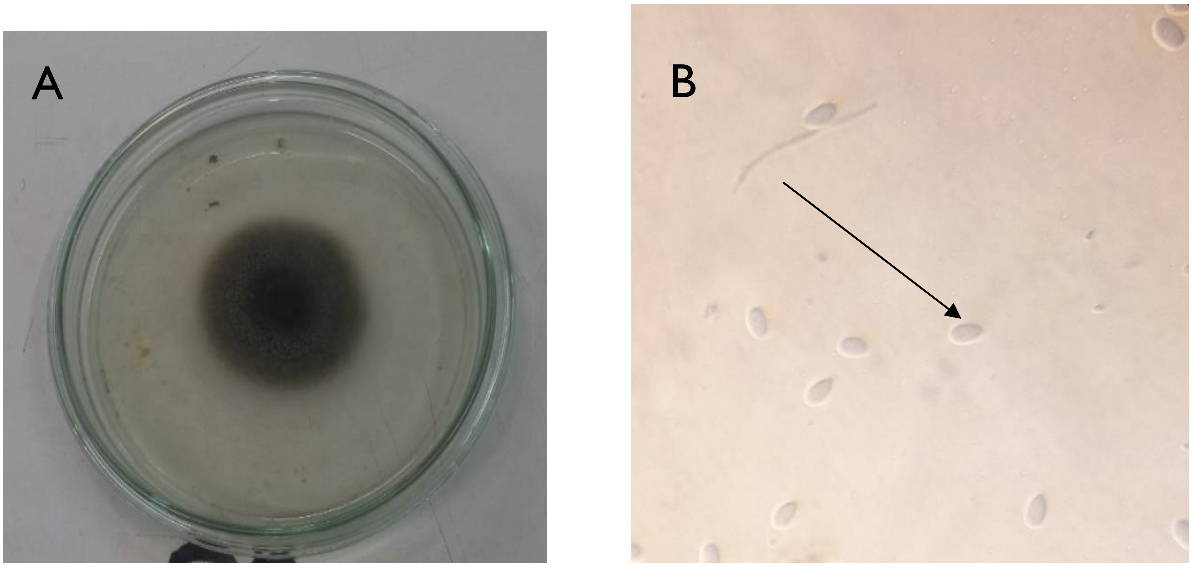

Plate 4.3 Culture (A) and micrograph (B) of *Colletotrichum gloeosporiodes*

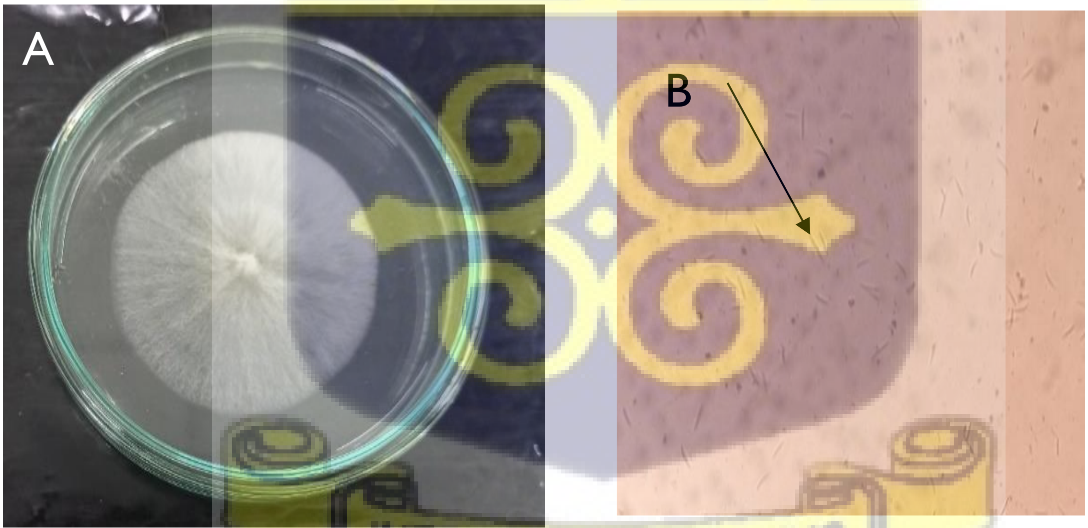

Plate 4.4 Culture (A) and micrograph (B) of *Fusarium spp.*

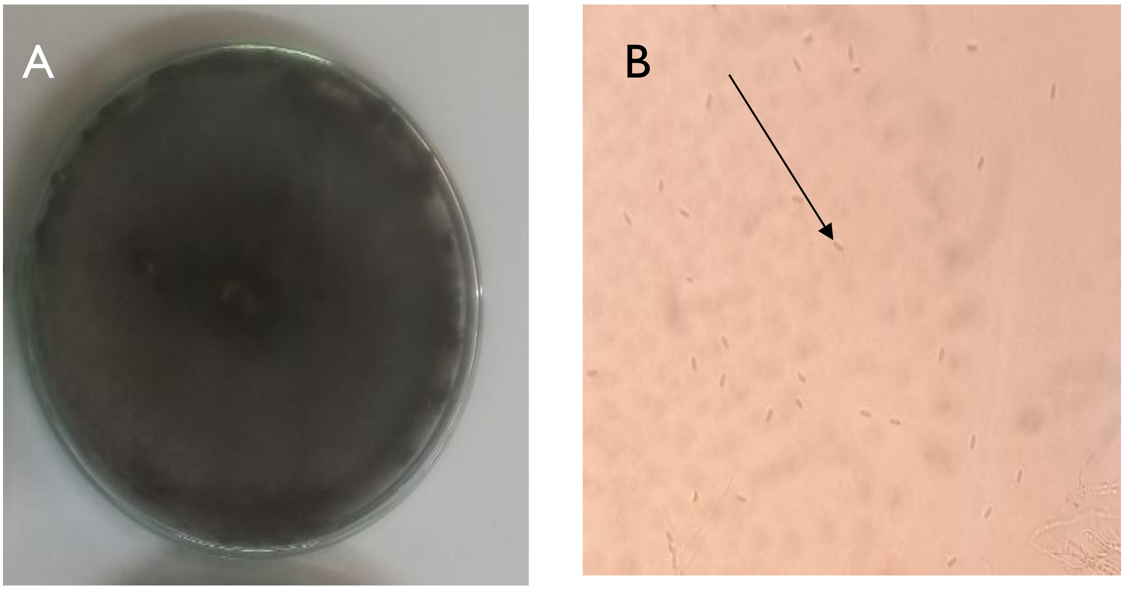

Plate 4.5 Culture(A) and micrograph (B) *Lasiodiplodia theobromae*

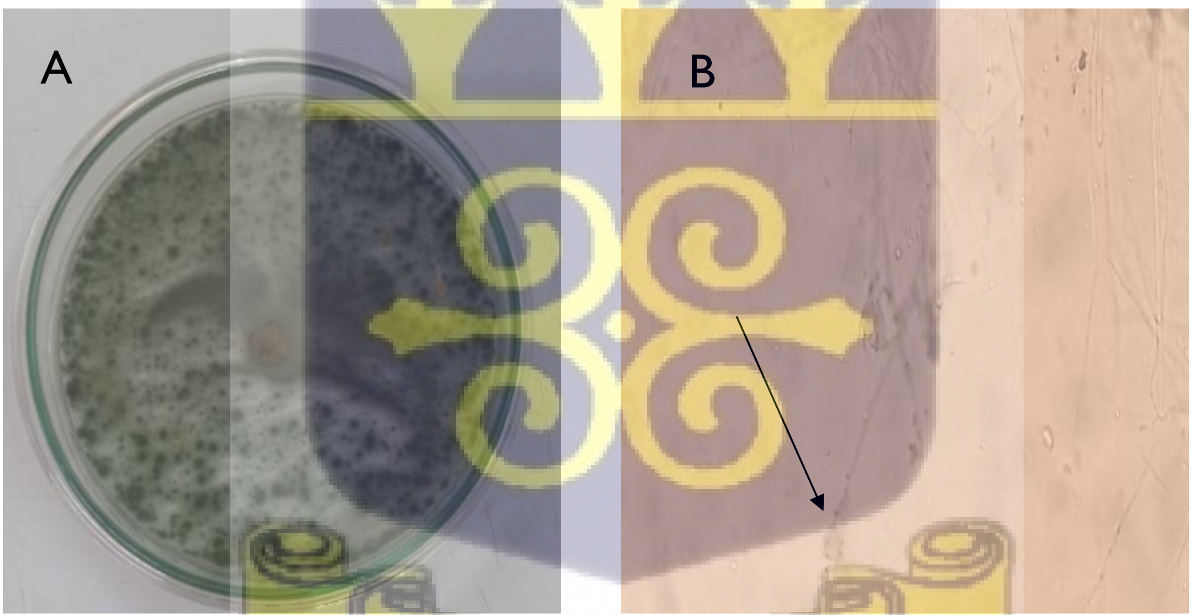

Plate 4.6 Culture (A) and micrograph (B) of *Penicillium*

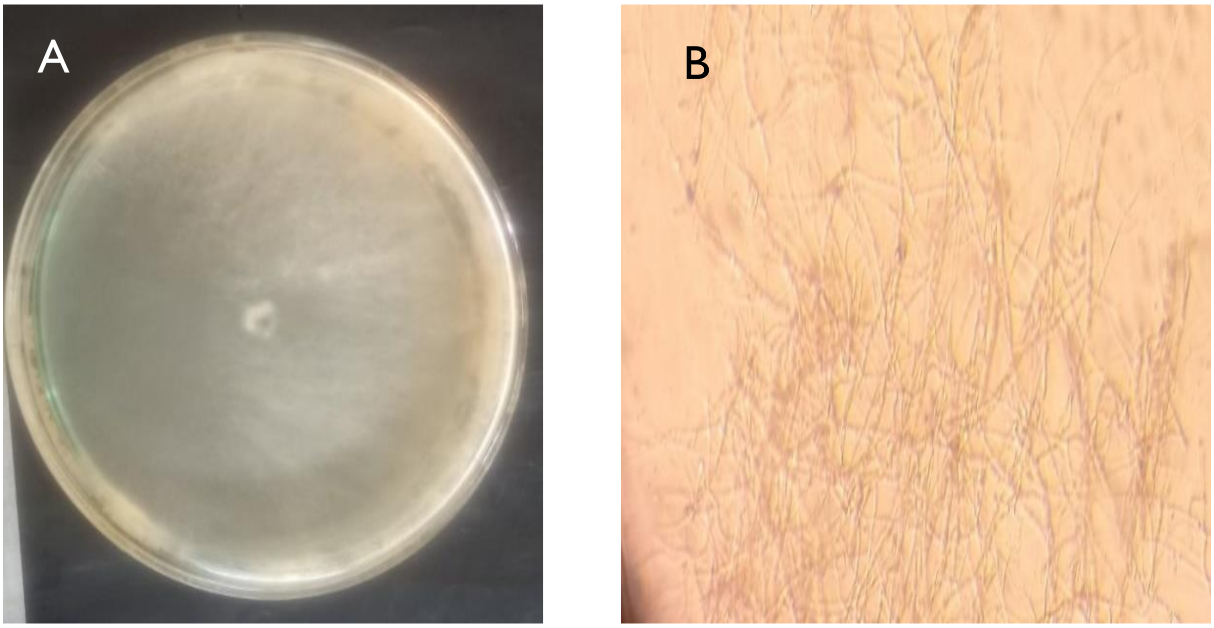

Plate 4.7 Culture (A) and micrograph (B) of *Fante kenkey like fungus* (unidentified)

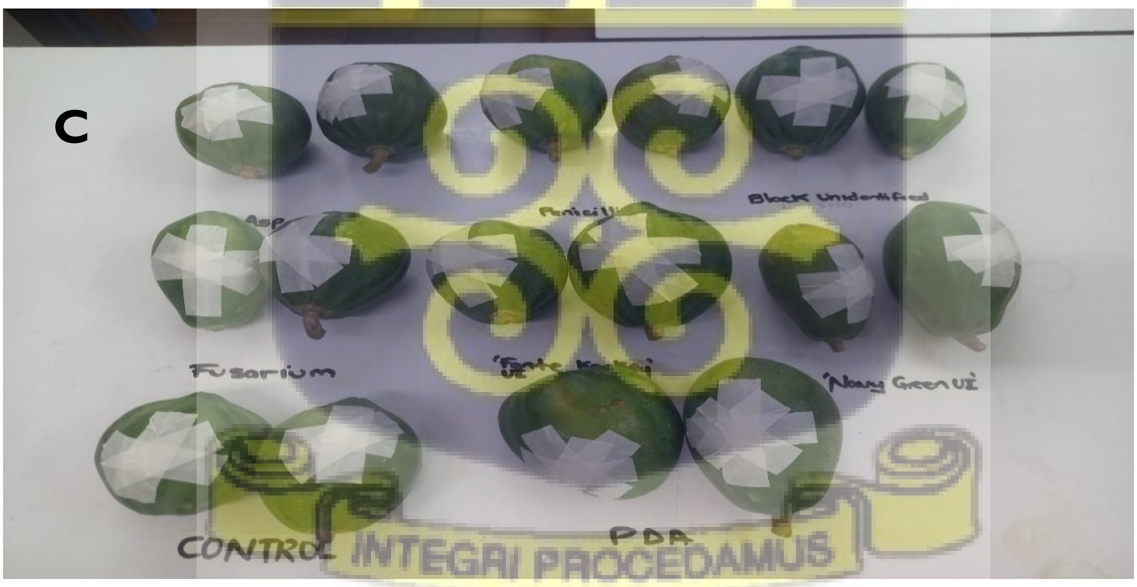

Plate 4.8 Infection of healthy fruits with pathogens

Plate 4.9 Infected healthy fruits (E) showing disease symptoms C. gloeosporoides with (D) and (F) showing no symptoms (control)

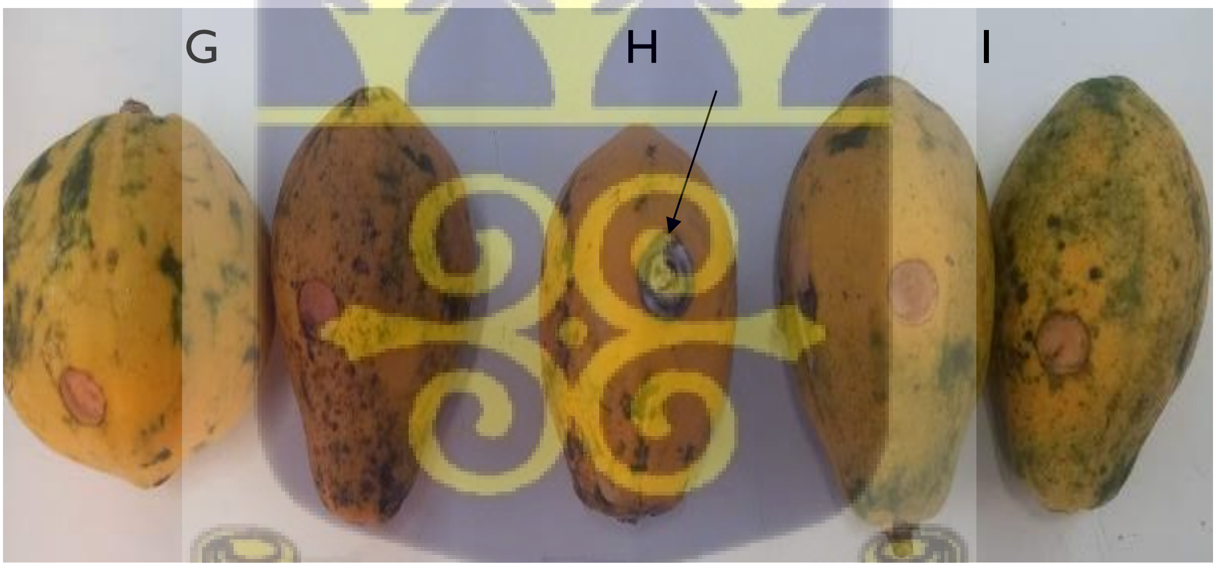

Plate 4.10 Infected health fruit (H) showing Fusarium spp. Symptoms whiles (G) and (I) show no symptoms

CHAPTER 5

5.0 Discussion

5.1 The post-harvest value chain of Papaya in the Nsawam-Adoagyir District

All farmers use a purchasing system that results in little or no loss on the farm (pre-arranged market). This assists farmers in avoiding problems associated with storing harvested fruits on the farm, such as rodent and insect attacks, diseases, sunburns, and theft. The use of vans to transport fruits is not the best mode of transportation. Since these vans are not designed to transport fruits, it can cause bruising.. (Atanda *et al*., 2011). The majority of traders did not protect their fruits during transportation. This exposes the fruits to the weather, resulting in physical, quality losses and increased disease incidence. The vast majority of farmers were not served by extension agents. However, because the majority of farmers were educated and belonged to a farmer-based organization they sourced help from each other even including purchasing of seeds. Nonetheless, a strong extension network will enable modern technology to be disseminated more widely (Paltasingh & Goyari, 2018).

5.2 Level of Education

From this study, majority of farmers (92.5%) and traders (75%) were educated. This is advantageous in terms of post-harvest losses and their impact on food security and safety This is because it will require the least amount of resources to teach the stakeholders in the *Papaya* value chain to recognize, appreciate, and adopt the significance of postharvest losses and its management. Education changes the atttudes of farmers making them more inclined to technological changed and it enhances agricultural productivity by improving farmers' decision-making ability and alleviating their technical efficiency (Appleton & Balihuta, 1996; Oduro-ofori *et al*., 2014).

According to Oduro-ofori *et al*., (2014)as educational level increases, output increases with secondary school education having the highest returns on agricultural productivity. Both society and the farmers as individuals gain from improved information. This assertion is also supported by a study that used linear regression analysis to investigate the effects of education on agricultural productivity in Benin. According to the findings, education not only improves agricultural productivity in the aftermath of technology, but it also encourages adoption (Jacquet *et al*., 2022). Likewise. when traders gain greater insights, they use this information to create value for customers (Dhruv G.& Motyka S., 2018).

5.3 Implication of harvesting practices Harvesting

According to the study, half of the farmers (51%) harvested their fruits at the mature unripe (green) state. This is consistent with best practices. According to De la Cruz *et al*., (2003), fruit should be harvested when the skin color changes from dark green to light green and one yellow streak begins to develop from the base of the fruit upward,. After harvest, fruit in this condition will continue to ripen normally. However, if harvested before or after this stage, *Papaya*s will either fail to fully ripen (if picked too early) or become more prone to damage and bruising during handling (if picked too late).

All of the farmers harvested their fruits by hand with knives or hand twisting. According to De la Cruz *et al*.,(2003) this is the most common method of harvesting; depending on the size and age of the tree.. To reach fruit at the top of tall trees, harvesters use a long pole with a small hoop and a small, mesh bag at the end.

5.4 Packaging

Most of the players in the papaya value chain used, plastic crates, wooden, aluminum trays and cane woven containers to convey their fruits. Crop-appropriate, clean and well ventilated Containers should be used. (Atanda *et al*., 2011). Baskets are inexpensive, but they have poor stacking strength, and when stacked on top of one another, the weight of the baskets is carried by the produce rather than the basket, causing crop damage due to compression. Their rounded, often irregular shape, makes baskets difficult to stack. Furthermore, when compared to boxes with squared corners, this results in poor space utilization. Reused baskets are difficult to clean and may harbor insect or microbial contamination. (Zhou *et al*., 2014).

Where fruit is harvested for transport to wholesale and retail markets, wooden boxes are used. They have the advantage of being able to be packed flat when empty and being inexpensive. They do, however, offer only limited protection against mechanical damage during transport. Plastic crates are ideal for maintaining fruits and vegetables. They are recyclable and reusable due to their strength and durability. Many are designed to nest inside each other when empty and stack one on top of the other when full. Plastic crates, when properly constructed, are strong, stack well, and have a smooth surface. This means that they protect the produce during handling and transportation. They are completely water resistant and thus simple to clean. However, expensive, so each box must be used numerous times to be cost effective (Atanda *et al*., 2011).

5.5 Post-harvest losses

Most farmers (53%) attributed most losses to mechanical damages during harvesting and handling. Fresh horticultural crops are high in water content and are subject to desiccation (wilting, shriveling) and to mechanical injury. post-harvest food losses in perishable produce are product of many variables which are inter-woven.(Ali et al., 2013)

When harvesting and handling operations are not performed carefully, crop damage occurs which hastens deterioration during subsequent marketing and storage operations resulting in losses. The majority of losses occurred at harvesting followed by packaging as a result of mechanical, physiological and pathological damage (Jayasheela *et al*., 2015; Thompson *et al*., 2018).

.According to Thompson *et al*., (2018), careless handling while harvesting, packing, transporting, storing produce and some activities of insects and birds can lead to mechanical damages, cuts can be inflicted where knives are used during harvesting or in opening boxes of packed fruits, overturning of boxes of fruits could cause bruising. Scuffing occurs when cuticle and cell layers are scraped away by abrasion. Bruising occurs as a result of either the crop being dropped or something striking it. This results in visible on the crop's surface or internal damage. And may be as a result of overfilling boxes and then stacking the boxes so that the crop in the lower boxes supports the weight; the higher their moisture content: the more they are susceptible.

According to this interview, farmers harvested fruits using ladders and manual hand twisting or knives. This is very time consuming, according to Thompson *et al*., (2018), and various methods have been devised to speed up the operation. A long pole with a bag at the end and some sort of device for cutting or breaking the fruit stalk are commonly used. There are picking platforms available that allow the harvester to be towed around the orchard from tree to tree so that the platform can be raised and lowered, allowing the fruit to be picked. It is also important to consider how the fruit is removed from the tree. Grapefruit are clipped from the tree in California, which is thought to reduce fungal infections, whereas in Florida, they are harvested by twisting and pulling, which has been shown to increase rotting. Crop hygiene is also important in reducing field infections and infestations that may enter storage or the marketing chain (de Oliveira & Vitória, 2011).. This typically entails removing rotting material from the field and effective weed control. One of the most common symptoms of deterioration, according to Kitinoja & Kader, (2015), is the activity of bacteria and fungi. Most organisms attack after physical injury or physiological breakdown of the commodity. Pathogens can infect healthy tissues and become the primary cause of deterioration in a few cases. During the majority of their postharvest life, fruits and vegetables show significant resistance to potential pathogens. The onset of ripening in fruits and senescence in all commodities makes them vulnerable to pathogen infection.

Most papaya traders suffered losses due to rot (61%) and rodents (39%) during storage and sale. The use of tarpaulin, plain (transparent) and black polythene sheets used to cover fruits may trap heat and create an unfavorable warm environment that accelerates deterioration. These findings are similar to those of Lamptey, (2013). In that study, it was discovered that some transporters used plain or black polythene sheets and tarpaulins, resulting in massive losses during the transportation and storage of watermelon fruits. The most serious loss encountered was rot. Diseases can cause discolouration of fruits as well as the development of undesirable flavors, resulting in a loss of fruit quality. As a result, it may result in outright consumer rejection as well as severe economic losses Rodents also bore holes in fruits, causing the fruit to rot. Generally, if a crop has suffered an infection during development its storage or marketable life may be adversely affected. (Thompson, 2003).

5.6 Shelf life

Shelf life refers to the maximum period between which fruits are harvested and the time it becomes unfit for the market or consumption (Vipan *et al*., 2018). Fruits stored in refrigeration temperature (10°C) had a longer shelif life twenty-one (21 days) compared to ambient temperature (27°C) storage with shelf life of nine (9) days.Coated fruits had longer shelf life than uncoated fruits. A much Longer shelf life was observed among 1% CMC, 3% Pro and 1%CMCNO coated fruits in both storage temperatures. This means that, the coating materials slowed down the rate of respiration, the antifungal activity of proccloraz and neem oil did not encourage the rapid build-up of carbon dioxide and delayed microbial growth. In ambient temperature, fruits costed with 1% CMC, 3% Pro and 1%CMCNO had a shel life of 15 days compared to the control of 6 days. Whiles in refrigeration temperature (10°C) 1% CMC, 3% Pro and 1%CMCNO had longer (27) days compared to the control with the shortest (21) storage days.

According to Prasad & Paul, (2021), fruits harvested at the color break stage and stored at 25–28 °C will ripen within 4-6 days, but can be stored for 14–21 days at 10 °C. In this study *Papaya* in ambient (27°C) and refrigeration temperature (10°C) lasted 9 and 21 days respectively confirming studies by Prasad & Paul, (2021). However, due to the application of 1% CMC, 3% Pro and 1%CMCNO coatings papaya stored at ambient temperature lasted15 days and 27 (12 additional days) days in refrigeration temperature.

5.7 Weight loss

Weight loss of uncoated fruits were higher compared to coated fruits under both storage conditions. Fruits coated with 1%CMC had significantly ($p<0.05$) the least weight loss (8.87%) compared to the control which had the highest (10.9%) in ambient temperature(27°C/77%rh) storage. Similarly, 1%CMC coated fruits had the least significant weight loss (4.39%) of compared to the control which lost more (7.83%) in refrigeration temperature (10°C/67%rh). In a previous study, 21.3%, 18.1 % and 12.6% losses were observed in uncoated, aloe vera coated, and aloe vera + ascorbic acid coated *Papaya* fruits stored at room temperature (25°C) respectively (Koushesh Saba & Sogvar, 2016). Similar research by Vipan *et al*., (2018), 4.52%, 5.60% and 8.39 losses were observed in hydroxypropyl methylcellulose (HPMC), beeswax (BW) and shellac (SC) coated orange fruits respectively. These findings also confirm those of Maftoonazad and Ramaswamy (2005), who found 4% and 8% weight loss in methyl-cellulose treated avocado and untreated avocado. Coated fruits form a barrier that prevents water vapour and gaseous exchange, resulting in a lower weight loss compared to uncoated fruits. The removal and re-organization of natural wax on the fruit surface by brushing and washing, could also explain the higher postharvest weight loss observed in the uncoated control fruit (Magwaza *et al*., 2013).

Temperature had significant ($p<0.05$) impact on fruit storage Fruits stored in ambient temperature lost more weight compared to the fruits stored in the cold. Fresh *Papaya*'s respiration rate, reflects its rate of perishability, and is directly impacted by temperature (ilie *et al*., 2005). The climacteric increase in CO_2 and C_2H_4 production that occurs with ripening is increased by high temperature (22-27°C) and slowed down by low-temperature (10-13°C) storage. In order to increase shelf life, *Papaya*s should be stored at 10 °C (Prasad & Paul, 2021).

CMC is an effective gas and moisture barrier. It creates a semi-permeable membrane, CMC has proved to lengthen fruit storage life when applied to fruits. This membrane slows down fruit deterioration by reducing metabolic processes, ethylene production, and disease infection (Elsabee & Abdou, 2013).

5.8 Firmness

Fruit softening was significantly higher in control fruits. Control fruits ripened earlier compared to coated fruits. This is owing to the degradation of pectins, cellulose, hemicellulose and polysaccharides that occurs during ripening as a result of enzyme activity on carbohydrate polymers (Al-Eryani-Raqeeb *et al.*, 2009; Workneh *et al.*, 2012). For both storage temperatures, edible coatings had a significant effect ($p < 0.05$) on fruit firmness Fruits in refrigeration temperature (10°C/67% rh) had higher firmness compared to ambient storage, 1%CMCNO had a higher mean firmness of (15.5N) in refrigeration temperature (10°C/67% rh) compared to (11.07N) in ambient temperature (27°C/77% rh) storage. Low oxygen and high carbon dioxide concentrations reduces enzyme (pectinase) activity and allows retention of the firmness in fresh produce. Furthermore, higher firmness of fruits stored in refrigeration temperature (10°C) could also be attributed to lower relative humidity and temperatures, which slow the fruits' transpiration and respiration rate. In a research by Ali *et al*., (2011), fruits coated with 2% chitosan had firmness of 84.4N, 1.5% chitosan (81N) and control (25.5N) firmness were observed in coated Eksotika *Papaya* fruits in refrigeration temperature (10°C) Other factors that influence fruit firmness include cell wall strength, cell-to-cell contact, and cellular turgor (Workneh *et al*., 2012). Moisture also loss affects the membrane structure and cell turbidity of fruits causing shriveling. The findings of this study are consistent with those of Botelho *et al*. (2016) who also illustrated reduced moisture loss in coated guava fruit. The improved barrier for gas and moisture diffusion could explain the increased firmness retention on coated fruit. Ethylene gas is one of the molecules that regulates the ripening process; however, it also reduces the storage of fruits (Tesfay *et al*., 2017).

5.9 Total soluble solids TSS

The total soluble solids of *Papaya* fruits were significantly ($p<0.05$) affected by edible coatings (Table.4.3). Throughout the study, ambient storage recorded higher TSS compared to refrigeration temperature (10°C). In this study a higher TSS of 9.72brix was observed in ambient temperature compared to refrigeration temperature with a low TSS of 9.21brix in fruits coated with 1%CMCNO.Higher temperatures and oxygen levels are responsible for this, as they boost transpiration rates, hasten ripening, and hasten the conversion of starch to simple sugars in fruits (Workneh *et al*., 2012). In a study by Vyas *et al*., (2014), 11.3brix and 13.3 brix was observed in 1%CMC coated and control *Papaya* fruits store at 25 °C for 21 days, respectively. Fruit's gradual increase in free sugars during storage periods has been linked to an increase in TSS for control treatment fruits (Brishti *et al*., 2013). By lowering respiration, coatings are known to slow the development of TSS. (Brishti *et al*., 2013; Sharmin *et al*., 2015). The T SS content increased to a peak and then declined during storage. According to Adetunji *et al*. (2013) the loss of soluble solids during storage is typically due to the use of sugars which makes up the majority of the fruits soluble solids content in the respiration and the metabolic processes of the fruit. TSS content decreased irrespective of the temperature regime during handling of bananas according to Nunes *et al*., (2013). The results of this study revealed that coatings had significant effect throughout storage conditions, therefore, they can be used to preserve *Papaya* fruit quality

5.10 pH

For both cold and ambient storage temperatures, the pH values increased with storage time for all treatments. However, coated fruits had higher pH compared to uncoated fruits. The higher pH values noted for coated fruits may be linked to a lower oxygen consumption and a rise in internal CO_2 than in control fruits, which is in line with the results of Adetunji, *et al*. (2013).

(Adetunji *et al*., 2013; Al-Eryani-Raqeeb *et al*., 2009).. Adetunji *et al*., (2013) observed a steady increase in the pH of cucumber stored under various conditions. 26℃. On day 24 and 27of refrigeration temperature (10℃), lower pH values were observed for all treatments. The pH values obtained in this research were higher under ambient storage conditions than under refrigeration temperature (10℃) conditions. The results disproves earlier reports by Escamilla-García *et al*., (2018), that pH on day 0 (0.21%) and day 16 (0.13%) and (0.11%) in chitosan-starch coated and control respectively, pH of *Papaya* fruits decreased under 25℃ storage conditions . Rapid respiration at high storage temperatures results in the production of acid in *Papaya* fruits Workneh *et al*., (2012),also discovered that room storage of *Papaya* fruits, as opposed to storage in an evaporative cooler, caused an increase in the rate of acid production from sugar catabolism. As a result, *Papaya* fruits require a low temperature to reduce respiration, which causes high acid production.

5.11 Titrable acidity TTA

Coating and storage conditions had no effect on TTA of *Papaya* fruits. This supports the findings of Arowora *et al*. (2013), who discovered no significant difference ($p>0.05$) in the titratable acidity of treated and untreated oranges. This study showed an increasing trend up to the 9th day before decreasing; day 0 (0.03 malic acid), day 9 (0.28) and day 15 (0.06) Singh & Sudhakar Rao, (2011) discovered a decrease in TTA of fruits wrapped in paddy straw during storage. The decrease at the end of storage could be attributed to internal metabolic changes caused by the use of organic acids in the metabolic process during ripening; this observation is consistent with Arowora *et al*. (2013). TTA values were lower in fruits in refrigeration temperature (10℃). The fruit's respiration rate decreases in a refrigeration temperature (10℃), resulting in a decreased acidity. according to Arowora *et al*. (2013). TTA ranged from 0.03-0.50 for ambient storage and 0.03-0.23 malic acid for refrigeration temperature (10℃) . Coated fruits had decreased TTA compared to control fruits as a result of coatings delaying respiration by altering both internal and external atmosphere of the fruit, leading to a slower consumption of respiration substrates such as organic acids and sugars (Workneh *et al*., 2012). As the fruit respires, the level of O_2 and CO_2 decreases and increases respectively. (Azene *et al*., 2014).

5.12 Vitamin C (Ascorbic Acid)

Vitamin C is an antioxidant that shields fruit from reactive oxygen. (Khaliq *et al*., 2015). The vitamin C content of *Papaya* fruits was significantly ($p<0.05$). affected by edible coatings. Coated fruits had significantly higher Vitamin C content compared to uncoated fruits with an increase during ripening and decrease once senescence began, per these findings, day 0 (2.71mg/mL), day 12 (4.92mg/mL) and day 15 (4.76mg/mL) vitamin C content was observed in fruits coated with 1%CMCNO. In a study by Langa,(2018) on *Papaya* in refrigeration temperature (10°C), day 0 (2.8mg/mL), day 10 (4mg/mL) and day 25 (3mg/mL), vitamin C content was observed in *Papaya* in refrigeration temperature (10°C) coated with moringa leaf extract + chitosan,. Khaliq *et al*., (2015), attributes this phenomenon to vitamin C being inherently lost during ripening when ascorbic acid reacts with oxygen during storage; autoxidation. Coatings slowed autoxidation by forming a protective layer on the fruit's surface that restricts the permeability of O_2 and CO_2 (Koushesh Saba & Sogvar, 2016). 1%CMCNO had significantly high vitamin C compared to the control with the least in both storages.

5.13 Pathogenicity

5.13.1Frequency of pathogens in storage conditions

Fusarium spp. was the most (54.54%), (81.81%) abundant fungi in both ambient and cold storage environments respectively. Hamim *et al*., (2014), reported that the frequently occurring diseases of papaya that causes significant damage during production and in storage were caused *by Colletotrichum gloeosporioides, Lasiodiploidia theobramae, Fusarium* spp. and *R. stolonifer.* In a study by Helal *et al.* (2018*),* 24.21% , 16.57%, 11.10%, and 1.48% frequency in *Fusarium* spp.*, C. gloeosporoides, L. theobromae and Aspergillus flavus* respectively were observed on *Papaya* stored in a box at 26°C/ 89.6% rh.

Ambient temperature (27°C/ 77% r h) had more six (6) disease isolates compared to three (3) in refrigeration temperature (10°C/67% rh). *Colletotrichum gloeosporoides, Fusarium* spp., Lasiodiplodia theobromae was common in both storage temperatures however, in ambient temperature storage. Aspergillus flavus, Penicillium, and an unidentified fungus (Fante kenkey-like) were additional fungus isolated. High temperature (above 30°C) and relative humidity (above 90%) hasten ripening which makes fruits susceptible to decay brought on by microbial pathogens.

Also, exposure to the open as compare to the enclosed refrigerator environment increases disease incidence in ambient/room storage. In addition, Field inoculums from dead infected plant parts infect crops, conidia remain dormant until exposure to moist environment then it develops appressoria and infect the fruit when ripe. At which stage symptoms begin to show (Hernandez-Montiel *et al*., 2018)

5.13.2 Pathogen incidence among coatings

Fruits in ambient temperature (27°C/77%) storage had higher disease incidence compared to fruits in refrigeration temperature (10°C/67%). Treatment 1%CMCNO coated fruits had the highest disease incidence (36.67%) in ambient temperature compared to refrigeration temperature (23.33%) storage. Significant difference ($p<0.05$) were observed in disease incidence in coated and uncoated fruits; High temperature (30°C)) and relative humidity (90%) increase respiration which speeds up ripening. Ripening increases fruit susceptibility to microbes. On the other hand, low temperature slows down respiration, metabolic and enzyme activity leading to low microbial incidence. control fruits had the highest (81.81%) disease incidence compared to 1%CMCNO coated fruits with the least incidence (36.67%) in ambient temperature storage. Similarly, in refrigeration temperature condition control had significant disease incidence of (54.54%) compared to 1%CMCNO coated fruits with the least incidence of 23.22%.). Edible coatings prevent crops from direct contact with microorganisms by functioning as a protective layer (Hasan *et al*., 2020; Chaudhary *et al*., 2020).

The combination of CMC with antimicrobials, tend to reduce antimicrobial diffusion, resulting in a less disease incidence as compared to simply applying the antimicrobial (de Oliveira & Vitória, 2011; Zillo *et al*., 2018).

CHAPTER 6

6.0 CONCLUSION AND RECOMMENDATION

6.1 Postharvest value chain of *Papaya* in the Nsawam Adoagyir District

Majority the farmers (85.4%) and traders (75%) who were interviewed had some level of education. Farmers interviewed did not have to grapple with storage of their harvested crops since they prearrange for market. Harvesting was mostly done manually and on time at the right maturity stage. Most (65.9%) losses occurred at harvest due to careless handling causing mechanical damages to the fruits. Traders (55%) on the other hand encountered losses due to rot and rodents attack during storage. Majority (92.5%) of farmers and traders (75%) did not have knowledge of edible coatings.

Edible coatings had significant effect in maintaining quality of *Papaya* fruits compared to the controls under both storage temperature conditions. However, refrigeration temperature storage-maintained fruit quality better compared to ambient temperature storage. Papaya under ambient and refrigeration storage lasted 9 and 21 days respectively. The application of 1% CMC, 3% Pro and 1%CMCNO coatings caused *Papaya* stored at ambient temperature to last 15 days and refrigeration temperature, 27 days (12 additional days). Treatments 1%CMCNO efficiently maintained physicochemical properties and suppressed disease incidence of *Papaya* in both storage conditions.

Nine (9) fungi were isolated in both storage conditions; six (6) in ambient and three (3) in refrigeration storage. *Colletotrichum gloeosporoides, Fusarium* spp., *Lasiodiplodia theobromae Aspergillus flavus, Penicillium,* unidentified fungus (Fante kenkey like) were isolated and identified from papaya in both storage temperature conditions. *Fusarium* spp. was the most abundant pathogen isolated in both storage conditions

6.2 RECOMMENDATION

The *Fante kenkey like* fungus should be morphologically and molecularly identified

Assessment of postharvest management practices should be conducted in the other major *Papay*a growing regions.

Sensitization and promotional seminars be conducted to educate players in the value chain about edible coating technology.

Performance of edible coatings should be investigated on the different varieties of *Papaya*

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APPENDIX

APPENDIX 1

Evaluating postharvest knowledge systems

Questionnaire for farmers only

DEMOGRAPHY (Please tick [√] where applicable)

General Information

1. Sex: Male [ ] Female [ ]

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

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

e) Separated [ ]

EDUCATIONAL BACKGROUND

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

Other [ ] (Please specify)……………………………………………

5. What type(s) of work do you do in addition to farming?

a) Mason, construction work, etc
b) Artisan (blacksmith, carpentry, tailoring)
c) General trade in agricultural produce
d) General trade in non-agricultural produce
e) Student
f) Others(specify)

6. How long have you been farming? Below 6yrs [ ] 6 – 10 yrs [ ] 10 – 15 yrs [ ] Above 16 yrs [ ]

7. What is the size of your farm? ………………………………………………………………………..

8. How many times do you cultivate in a year? Once [ ] Twice [ ] Thrice [ ]

9. Where are seeds obtained from?

a) Own seeds
b) Fellow farmers or friends
c) Extension Agents (AEA)

d) Certified dealers/sellers

e) MOFA offices

f) Other (specify)......................

10. Do you apply any agro-chemicals? a) Yes [ ] b) No [ ]

11. In your opinion what are the practices that affect post- harvest quality?

……………………………………………………………………………………..

…………………………………………………………………………………………

…………………………………………………………………………………………

HARVESTING AND POSTHARVEST PRACTICES

Harvesting Operation

12. Do you prearrange for market before harvesting? Yes [ ] / No [ ]

13. At what time of the day do you usually harvest your produce?

(a) Morning [ ] (b) Afternoon [ ] (c) Evening [ ] (d) No specific time [ ]

14. Do you have any special reason for harvesting at a specific time of the day? Yes [ ] / No [ ]

15. If yes, please explain?

...……………………………………………………………………………

16. At what stage of maturity do you harvest your produce?

(a)Mature unripe [ ] (b) Half ripe [ ] (c) Yellow ripe [ ] (d) other [ ] (Please specify)…………

17. How do you harvest your fruit? (a) Manual [ ] (b) Mechanical [ ]

18. If manual, please specify. a) By knife cutting [ ] b) by hand twisting [ ]

19. If mechanical indicate equipment use.

……………………………………………………………………………….

……………………………………………………………………………….

20. Do you incur some losses during harvesting? a) Yes [ ] b) No [ ]

21. If yes, what losses do you suffer? a) Mechanical [ ] b) Physiological [ ] c) Rotting [ ]

22. What is the estimate quantity of loss suffered?

Please specify..

Losses at Storage and Storage Practices

23. Is there a ready market for your produce? Yes [ ] / No [ ]

24. Where are fruits stored? a) On the farm b) at home c) other specify)…………………

25. How do you store your produce in case there is no ready market?

(a)Stored in a specially conditioned storage facility [ ] (b) Poured on bare cemented floor [ ] (c) others [ ] (Please specify)
……………………………………………………………………………………………

26. Briefly describe how fruits are stored

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

27. Describe the environment/conditions under which fruits are stored

…………………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

28. Is the storage method chosen usually able to store your produce to prevent / reduce spoilage? Yes [ ] / No [ ]

29. If "Yes", did you acquire this knowledge through a special training in storage? Yes [ ] /No [ ]

30. If yes, where did you get this special training?

(a) School [ ] (b) Farmer's forum [ ] (c) MoFA farmers" field day [ ] (d) Traditional [ ] (e) Other [ ] (Please specify)…………………………………………………………………….

31. Are you willing to adopt innovative storage methods if they prove more effective than what you currently use? Yes [ ] / No [ ]

32. What are the major challenges you face during storage?

....

33. Do you incur some losses during Storage? a) Yes [ ] b) No [ ]

34. If yes, what losses do you suffer? a) Mechanical [ ] b) physiological [ ] c) Rotting [ ]

35. What is the estimate quantity of loss suffered? Please specify...

Losses at Packaging and Packaging Practices

36. What packaging material do you use for your produce? (a)Shallow wooden boxes [ ] b) Long big wooden boxes [ ] (c) Plastic basket [ ] d) cane basket [ ]

e) Other [ ] (please specify)………………………………………………………

37. Do you subject the produce to any special condition(s) before packaging them for market? Yes [ ] / No [ ]

38. If "Yes", can you share it/them with us?

………………………………………………………………………………………

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

40. What is the estimate quantity of loss suffered?

Please specify..

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

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

Farmers Perception on Coating of *Papaya* Fruit after Harvest.

42. Do you know of coating?

(a)Yes [ ] (b) No [ ]

43. Do you employ coating to your *papaya* fruits after harvest? (a)Yes [ ] (b) No [ ]

44. If "Yes", what are your reasons for using the coating material in storage of the *papaya* fruit after harvest?

……………………………………………………………………………………………

………………………………………………………………………………………………

45. What type of coating material do you use? (a) Cassava starch [ ] b) carboxylmethyl cellulose [ ] c) chitosan [ ] d) carageenan [ ] e) Any other specify………………………

46. Do you know any modern storage technology of *papaya* fruit after harvest? Yes [ ] No.

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

Postharvest Losses and Practices

48. In your opinion where do you think most of the losses occur from the point of harvest to the point of sale? a) Harvesting [ ] b) Sorting [ ] c) Storage [ ] d) Packaging [ ] e) Transporting [ ] f) Marketing [ ]

g) Other [ ] (please specify)…………………………………………………………

49. Describe the type of loses incurred.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

50. What is the estimate quantity of loss suffered?

Please specify...

51. What are the various causes of postharvest losses of *papaya* in your community? (Tick as many as applicable)

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

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

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

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

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

53. Do you receive any form of help from Agric Extension Agents (AEA's)

Yes [ ] No [ ]

54. If yes, describe the nature and type of services you receive from extension agents?

....

....

....

....

APPENDIX 2

Questionnaire for traders (wholesalers/retailers)

DEMOGRAPHY (Please tick [√] where applicable)

General Information

1. Sex: Male [ ] Female [ ]
2. Age range: Below 18 years [ ] 18 – 24 yrs [ ] 25 – 40yrs [ ] 41 -55 yrs [ ] above 55 yrs [ ]

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

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

Other [ ] (Please specify)……………………………………………………

5. How long have you been trading in *papaya*? (a) Below 1 year [ ] (b) 1 – 4 years [ ] (c) 5 – 8 years [ ] (d) Over 8 years [ ]

6. How would you assess the rate of *papaya* spoilage in your area over the years? a) Very high [ ] b) High [ ] c) Low [ ] d) Very low [ ] e) Stable [ ] f) Reducing [ ]

7. Which of the following accounts for the losses? (Tick as many as applicable)

(a) Lack of ready market [ ] (b) Lack of transport of produce [ ] (c) Lack of storage facility [ ] (d) Lack of storage technology [ ] (e) Pest attack [ ] (f) others [ ] (Please specify……………………

8. Where do you obtain your fruits from? (a) Own farm [ ] (b) Purchase from farmers [ ] (c) Purchase from wholesalers [ ] (d) Purchase from retailers [ ]

9. How do you usually transport purchased produce to your point of sale?

a) By vehicle [ ] b) By any available head-loaded porter [ ]

c) Any other [ ]..................................

10. What type of vehicle do you use to transport your produce?

a) Open truck [ ] b) Van or roofed truck [ ] c) Other [ ]

Please specify: ………………….

11. What materials are used to cover fruits during transportation?

a) Tarpaulin [ ] b) Black polyethene sheets [ ] c) Straw [ ] d) No cover [ ] e) Other [ ]

Please specify: ………………….

12. In your opinion how would you rate the condition of your vehicle in transporting the goods? a) Very good [ ] b) Good [ ] c) Average [ ] d) Bad [ ] e) Very bad [ ]

13. In your own assessment, what is the condition of the road network that you use? a) Very good [ ] b) Good [ ] c) Average [ ] d) Bad [ ] e) Very bad [ ]

14. Where are fruits stored? a) At the market [ ] b) At home [ ]

c) In a warehouse/store room [ ] d) Other (specify)…………………………….

15. How are fruits stored?

……………………………………………………………………………………………

……………………………………………………………………………………………

………………………………………………………………………………………………

…………………………………………………………………………………………

……………………………………………………………………………………………

16. Describe the environment/conditions under which fruits are stored

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………

17. What is/are the major challenge(s) encountered during storage of the fruits?

a) Insect [ ] b) rodents [ ] c) rot [ ] d) thieves [ ] e) weight loss [ ]

f) Other (specify)

18. Do you incur commodity losses from the point of purchase to the point of sale?

a)Yes [ ] b) No [ ]

19. If "yes", what losses do you suffer? a) Quantitative loss [ ] b) Qualitative loss

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

a) ……………………………………………………………………………………..

b) ……………………………………………………………………………………..

c) ………………………………………………………………………………………

21. What is the estimate quantity of loss suffered?

Please specify..

22. Do you perform any form of preservation? a) Yes [ ] b) No [ ]

23. If “Yes” Please give reasons

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

24. Did you learn this skill from a special training? Yes [ ] / No [ ]

25. From which organization did you get this training? (a) Traders association [ ] (b) MoFA staff [ ] (c) NGO [ ] (d) Others [ ]

Please specify)……………………………………..............

26. Do you know of waxing? (a)Yes [ ] (b) No [ ]

27. Do you employ waxing in the storage of your *papaya* fruits?

(a)Yes [ ] (b) No [ ]

28. If “Yes”, what are your reasons for using the coating material in storage of the *papaya* fruit?

………………………………………………………………………………………………

…………………………………………………………………………………………

29. What type of waxing material do you use? a) cassava starch [ ] b) carboxylmethyl cellulose [ ] c) chitosan [ ] d) carageenan [ ]

e) Any other specify……………………………………

30. Do you know any effective modern storage technology of *papaya* melon fruit that can extend it shelf life and improve it quality? a) Yes [ ] b) No [ ]

31. If "Yes", state.

……………………………………………………………………………….

……………………………………………………………………………….

………………………………………………………………………………

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

APPENDIX 3

Temperature and humidity recordings for evaluating the performance of carboxylmethyl cellulose film incorporated with plant oils on the physical and chemical characteristics of *Papaya*

(*carica papaya l.)* in ambient storage

Device Information				
Device Model	TemLog20H	Probe Type	Temperature&Humidity(Internal)	
Serial Number	HM1190700075	Firmware V	V1.4	
Trip Description				
Trip Number	0000001			
Trip Description	Temperature recording.			
Parameter Configuration				
Start Mode	Press Button	Logging Inte	1H 0M 0S	
Start Delay	0H0M	Circular Lo	Disable	
Time Zone	UTC +00:00	Stop Mode	Temporary Stop	
Mark Time				
N/A				
No Alarm				
Summary				
Max	28.8°C/84.0%	First Readi	2022-07-26 17:33:39	
Min	25.3°C/65.3%	Last Readin	2022-08-17 10:33:39	
Avg	26.8°C/76.7%	Logging Du	21D 17H 0M 0S	
MKT (Mean Kinetic Temperature)	26.8°C	Current Rea	522	

Temperature and humidity recordings for evaluating the performance of carboxylmethyl cellulose film incorporated with plant oils on *Papaya* postharvest pathogens

Device Information					
Device Model	TemLog 20H		Sensor Type	Temperature & Humidity(Internal)	
Serial Number	HM1190700081		Firmware Version	V1.4	
Trip Description					
Trip Number	0000001				
Trip Description	Temperature recording.				
Config. info					
Start Mode	Press Button		Logging Interval	1:0:10	
Start Delay	0H0M		Repeat Start	Enable	
Time Zone	UTC +00:00		Stop Mode	Press Button + Use Software	
Light	Disable		Alarm Logging Interval Shorter	Disable	
N/A					
Alarm Threshold	Alarm Delay	Over-limit Duration	Over-limit Times	Alarm Status	
Summary					
Maximum	28.8°C / 81.4%RH		First Reading	8/23/2022 13:10	
Minimum	24.9°C / 43.9%RH		Last Reading	2022-08-24 10:13:48(Stop by button)	
Average	26.4°C / 68.4%RH		Logging Duration	30D 21H 3M 10S	
Mean Kinetic Temperature (M	26.4°C		Current Readings	740	
First Alarm(Temperature)	N/A		First Alarm(Humidity)	N/A	

Temperature and humidity recordings for evaluating the performance of carboxylmethyl cellulose film incorporated with plant oils on the physical and chemical characteristics of *Papaya*

(*carica papaya l.)* in refrigeration temperature (10°C)

Device Information			
Device Model	TemLog20H	Probe Type	Temperature&Humidity(Internal)
Serial Number	HM1190700081	Firmware V	V1.4
Trip Description			
Trip Number	0000001		
Trip Description	Temperature recording.		
Parameter Configuration			
Start Mode	Press Button	Logging Inte	1H 0M 10S
Start Delay	0H0M	Circular Lo	Disable
Time Zone	UTC +00:00	Stop Mode	Press Button
Mark Time			
N/A			
No Alarm			
Summary			
Max	25.9°C/95.0%	First Readi	2022-07-26 17:28:52
Min	3.4°C/32.3%	Last Readin	2022-08-24 15:24:12
Avg	10.1°C/67.1%	Logging Du	28D 21H 55M 20S
MKT (Mean Kinetic Temperature)	10.5°C	Current Rea	693
First Alarm at (Temperature)	N/A	First Alarm	N/A

APPENDIX 4

ANOVA 1: Variate: Percentage Weight_loss_%

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ Temp	1	670.3823	670.3823	897.95	<.001
+ Coating	10	573.6719	57.3672	76.84	<.001
+ Days	8	1586.9337	198.3667	265.71	<.001
+ Temp.Coating.Days	105	545.9787	5.1998	6.96	<.001
Residual	170	126.9163	0.7466		
Total	294	3503.8828		11.9180	

ANOVA 2: Variate: Percentage Weight_loss Cold

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
+ Temp	0	0.0000	*		
+ Coating	10	451.7868	45.1787	128.01	<.001
+ Days	8	1119.9323	139.9915	396.67	<.001
+ Temp.Coating	0	0.0000	*		
+ Temp.Days	0	0.0000	*		
+ Coating.Days	69	182.1700	2.6401	7.48	<.001
Residual	122	43.0562	0.3529		
Total	209	1796.9453	8.5978		

ANOVA 3: Variate: Firmness (N) Ambient*Cold

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
+ Temp	0	0.0000	*		
+ Coating	10	357.9672	35.7967	42.36	<.001
+ Days	5	2829.7332	565.9466	669.76	<.001
+ Temp.Coating	0	0.0000	*		
+ Temp.Days	0	0.0000	*		
+ Coating.Days	32	171.0724	5.3460	6.33	<.001
Residual	66	55.7695	0.8450		
Total	113	3414.5424	30.2172		

ANOVA 4: Variate: Firmness (N) Cold

Sources of variation	d.f.	s.s.	m.s.	v.r.	F pr.
+ Temp	0	0.0000	*		
+ Coating	10	268.9846	26.8985	59.94	<.001
+ Days	9	1073.6191	119.2910	265.81	<.001
+ Temp.Coating	0	0.0000	*		
+ Temp.Days	0	0.0000	*		
+ Coating.Days	79	157.5203	1.9939	4.44	<.001
Residual	144	64.6255	0.4488		
Total	242	1564.7495	6.4659		

ANOVA 5: Variate: Brix Ambient*Cold

Sources of variation	d.f.	s.s.	m.s.	v.r.	F pr.
+ Temp	0	0.0000	*		
+ Coating	10	49.6586	4.9659	10.94	<.001
+ Days	5	257.3049	51.4610	113.33	<.001
+ Temp.Coating	0	0.0000	*		
+ Temp.Days	0	0.0000	*		
+ Coating.Days	32	73.0619	2.2832	5.03	<.001

Residual	66	29.9686	0.4541		
Total	113	409.9940	3.6283		

ANOVA 6: Variate: Brix Cold

Sources of variation	d.f.	s.s.	m.s.	v.r.	F pr.
+ Temp	0	0.000	*		
+ Coating	10	18.427	1.843	1.66	0.096
+ Days	9	248.236	27.582	24.83	<.001
+ Temp.Coating	0	0.000	*		
+ Temp.Days	0	0.000	*		
+ Coating.Days	79	95.123	1.204	1.08	0.335
Residual	144	159.982	1.111		
Total	242	521.768	2.156		

ANOVA 7: Variate: Vitamin C_(mg_/ml) Ambient*Cold

Sources of variation	d.f.	s.s.	m.s.	v.r.	F pr.
+ Temp	0	0.00000	*		
+ Coating	10	20.93901	2.09390	148.50	<.001
+ Days	5	61.62174	12.32435	874.04	<.001

+ Temp.Coating	0	0.00000	*		
+ Temp.Days	0	0.00000	*		
+ Coating.Days	32	15.23100	0.47597	33.76	<.001
Residual	66	0.93063	0.01410		
Total		113	98.72238		
0.87365					

ANOVA 8: Variate: Vitamin C_(mg/_ml) Cold

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ Temp	0	0.00000	*		
+ Coating	10	20.00037	2.00004	79.70	<.001
+ Days	9	132.26086	14.69565	585.58	<.001
+ Temp.Coating	0	0.00000	*		
+ Temp.Days	0	0.00000	*		
+ Coating.Days	79	35.44742	0.44870	17.88	<.001
Residual	143	3.58873	0.02510		
Total	241	191.29738	0.79377		

ANOVA 9: Variate: pH Ambient*Cold

Sources of variation	d.f.	s.s.	m.s.	v.r.	F pr.
+ Temp	1	1.74284	1.74284	102.59	<.001

+ Coating	10	0.75988	0.07599	4.47	<.001
+ Days	5	15.44473	3.08895	181.82	<.001
+ Temp.Coating.Days	97	6.73516	0.06943	4.09	<.001
Residual	172	2.92213	0.01699		
Total	285	27.60473	0.09686		

ANOVA 10: Variate: pH Cold

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ Temp	0	0.000000	*		
+ Coating	10	0.336896	0.033690	4.48	<.001
+ Days	9	23.489928	2.609992	346.90	<.001
+ Temp.Coating	0	0.000000	*		
+ Temp.Days	0	0.000000	*		
+ Coating.Days	79	2.624872	0.033226	4.42	<.001
Residual	144	1.083433	0.007524		
Total	242	27.535129	0.113782		

ANOVA 11: Variate: TTA_% Ambient*Cold

Sources of variation	d.f.	s.s.	m.s.	v.r.	F pr.
+ Temp	0	0.00000	*		

+ Coating	10	1.16117	0.11612	2.06	0.041
+ Days	5	1.57447	0.31489	5.58	<.001
+ Temp.Coating	0	0.00000	*		
+ Temp.Days	0	0.00000	*		
+ Coating.Days	32	3.19404	0.09981	1.77	0.026
Residual	64	3.61018	0.05641		
Total	111	9.53986	0.08594		

ANOVA 12: Variate: TTA_% Cold

Sources of variation	d.f.	s.s.	m.s.	v.r.	F pr.
+ Temp	0	0.00000	*		
+ Coating	10	0.78720	0.07872	4.42	<.001
+ Days	9	2.04290	0.22699	12.73	<.001
+ Temp.Coating	0	0.00000	*		
+ Temp.Days	0	0.00000	*		
+ Coating.Days	79	7.26212	0.09193	5.16	<.001
Residual	142	2.53115	0.01782		
Total	240	12.62337	0.05260		

ANOVA 13; Variate: shelf life

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	
Coatings	10	104.364	10.436			
Storage_condition	1	929.500	929.500			
Coatings.Storage_condition	10	10.000	1.000	Total	21	1043.864

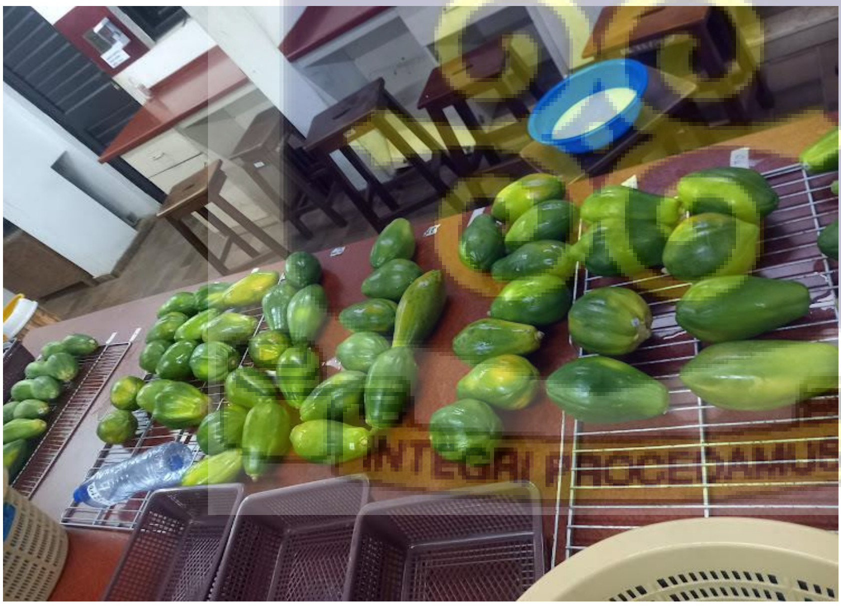
APPENDIX 5

ANOVA 14; Variate: Disease_Incidence

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatments	10	4315.15	431.52	8.32	<.001
Storage_Condition	1	4583.33	4583.33	88.39	<.001
Residual	54	2800.00	51.85		
Total	65	11698.48			

APPENDIX 6

Pictures from survey and physico-chemical work



Days of storage

	Coatings	3	6	9	12	15	Means
			Weight Loss (%)				
Ambient	1%CMC	3.69	6.64	8.85	12.2	13.47	8.97
	1%CMC1mLMO	4.28	9.17	13.34	*	*	8.93
	1%CMC3mLMO	6.18	8.67	11.55	*	*	7.43
	1%CMC1mLNO	3.60	6.58	10.79	12.52	12.28	9.16
	1%CMC3mLNO	4.11	7.51	12.79	*	*	8.14
	1%MO	2.81	6.28	9.58	*	*	6.22
	3%MO	4.70	6.86	7.19	*	*	6.25
	1%NO	5.27	11.16	10.27	*	*	8.90
	3%NO	4.20	7.59	8.39	*	*	5.90
	0.3%Pro	2.61	5.76	8.85	12.28	12.00	8.30
	CTRL	5.74	11.89	15.34	*	*	10.99
Cold	1%CMC	1.30	2.35	3.46	4.01	4.38	4.39
	1%CMC1mLMO	1.68	2.22	2.90	3.47	3.51	4.55
	1%CMC3mLMO	1.07	1.49	2.27	2.833	3.07	4.65
	1%CMC1mLNO	1.93	3.10	3.92	3.81	4.63	4.83
	1%CMC3mLNO	1.88	2.82	3.99	5.40	5.99	4.85
	1%MO	1.25	2.27	2.22	2.29	2.85	4.69
	3%MO	1.05	1.74	2.08	2.23	2.42	4.99
	1%NO	1.26	1.94	3.06	3.36	4.79	5.51
	3%NO	1.27	2.02	2.79	3.68	4.87	5.69

0.3%Pro	0.75	1.37	1.86	2.19	2.23	
CTRL	2.75	4.43	5.38	7.66	9.51	7.83
MEANS	2.89	5.18	6.86	5.57	6.14	
LSD(0.05)	Coating=0.50			Days=0.32	Coating * Days =1.60	

Coatings	Days of storage									Means
	3	6	9	12	15	18	21	24	27	
					Weight Loss (%)					
1%CMC	1.30	2.35	3.46	4.01	4.38	6.37	8.28	11.97	12.81	5.27

1%CMC1mLM	1.6	2.2	2.9	3.47	3.51	8.1	9.2	8.76	*	4.99
O	8	2	0			1	7			
1%CMC3mLM	1.0	1.4	2.2	2.83	3.07	4.4	7.0	7.31	*	3.70
O	7	9	7	3		8	7			
1%CMC1mLN	1.9	3.1	3.9	3.81	4.63	5.5	6.5	7.67	*	4.65
O	3	0	2			6	5			
1%CMC3mLN	1.8	2.8	3.9	5.40	5.99	6.6	7.5	10.6	*	5.62
O	8	2	9			7	7	7		
1%MO	1.2	2.2	2.2	2.29	2.85	3.5	4.4	7.80	*	3.34
	5	7	2			7	6			
3%MO	1.0	1.7	2.0	2.23	2.42	4.3	5.2	4.13		2.90
	5	4	8			3	0			
1%NO	1.2	1.9	3.0	3.36	4.79	5.2	6.6	*	*	3.75
	6	4	6			0	0			
3%NO	1.2	2.0	2.7	3.68	4.87	5.8	7.3	*	*	3.97
	7	2	9			5	3			
0.3 %PRO	0.7	1.3	1.8	2.19	2.23	4.6	6.2	6.46	7.19	3.22
CTRL	5	7	6	7.66	9.51	2	4	6.46	7.19	5.88
	2.7	4.4	5.3			4.6	6.2			
	5	3	8			2	4			
MEANS	1.5	2.3	3.1	3.70	4.40	5.4	6.8	7.9	9.10	
	0	1	3			0	0			

LSD’s (0.05)	Coatings=0.4	Days=0.3	Coatings*Days=1.1

		Days of storage						Means
		1	3	6	9	12	15	
		Firmness(N)						
Ambient	1%CMC	18.27	15.86	11.86	8.93	6.64	4.86	11.07
	1%CMC1mLMO	18.27	14.21	7.82	4.72	*	*	11.26
	1%CMC3mLMO	18.27	15.92	12.3	8.44	*	*	13.73
	1%CMC1mLNO	18.27	15.13	12.16	10.15	8.24	4.3	11.38
	1%CMC3mLNO	18.27	13.45	9.58	4.27	*	*	11.39
	1%MO	18.27	13.47	6.53	6.97	*	*	11.31
	3%MO	18.27	13.54	8.65	5.77	*	*	11.56
	1%NO	18.27	11.03	6.22	4.5			10.01
	3%NO	18.27	11.88	3.57	3.6	*	*	9.33
	0.3%Pro	18.27	15.44	13.05	10.28	7.05	5.21	11.55
	CTRL	18.27	9.29	4.55	2.17	*	*	8.57

Cold	1%CMC	18.27	16.6	15.13	14.46	13.54	12.52	15.09
	1%CMC1mLMO	18.27	15.87	15.12	13.76	12.66	10.15	14.31
	1%CMC3mLMO	18.27	16.85	15.82	14.85	12.79	11.51	15.02
	1%CMC1mLNO	18.27	17.32	15.63	14.9	12.94	11.86	15.15
	1%CMC3mLNO	18.27	14.43	15.81	13.11	12.92	13.04	14.60
	1%MO	18.27	16.84	13.46	13.14	12.99	12.65	14.56
	3%MO	18.27	16.57	15.03	14.58	14.45	14.31	15.54
	1%NO	18.27	14.42	13.97	13.17	12.42	13.03	14.21
	3%NO	18.27	15.59	14.02	13.7	13.54	13.52	14.77
	0.3%Pro	18.27	17.08	15.4	14.94	13.42	12.12	15.21
	CTRL	18.27	13.46	12.69	11.29	9.71	7.12	12.09
	MEANS	18.27	14.37	11.27	10.06	11.38	11.05	
LSD (0.05)		Coating=2.0	Days = 1.50		Coating * Days =6.0			

		Days of storage						
		1	3	6	9	12	15	Means
	Coatings			TSS(Brix)				
Ambient	1%CMC	7.20	8.04	10.27	10.43	9.78	9.90	9.27
	1%CMC1mLMO	7.20	10.57	11.27	10.75	*	*	9.95
	1%CMC3mLMO	7.20	9.77	11.40	*	*	*	9.46

	1%CMC1mLNO	7.20	9.70	10.43	10.50	9.78	9.20	9.47
	1%CMC3mLNO	7.20	8.43	10.40	11.00	*	*	9.26
	1%MO	7.20	11.32	10.73	10.60	*	*	9.96
	3%MO	7.20	11.23	6.55	9.80	*	*	8.70
	1%NO	7.20	11.78	11.80	11.05	*	*	10.46
	3%NO	7.20	10.18	10.7	*	*	*	9.36
	0.3%Pro	7.20	11.25	10.25	11.60	11.30	8.20	9.97
	CTRL	7.20	10.76	12.97	13.43	*	*	11.09
Cold	1%CMC	7.20	8.80	10.30	10.41	9.97	9.97	9.43
	1%CMC1mLMO	7.20	9.98	9.67	9.83	10.63	10.13	9.57
	1%CMC3mLMO	7.20	9.77	9.06	9.80	9.03	9.53	9.07
	1%CMC1mLNO	7.20	9.96	10.17	10.70	10.20	9.70	9.66
	1%CMC3mLNO	7.20	11.04	9.17	10.23	10.60	9.73	9.66
	1%MO	7.20	10.82	10.55	10.70	10.50	10.45	10.04
	3%MO	7.20	10.35	9.70	11.40	8.20	10.90	9.63
	1%NO	7.20	10.58	10.85	10.80	10.35	9.70	9.91
	3%NO	7.20	10.25	9.70	10.40	10.50	10.20	9.71
	0.3%Pro	7.20	9.15	8.10	10.60	10.90	10.05	9.33
	CTRL	7.20	10.36	9.70	10.67	10.47	10.73	9.856
Means		7.20	10.26	10.10	10.73	10.15	9.89	

LSD's (0.05) Coatings=0.56 Days=0.36 Coating*Days= 1.30

	Days of storage										
	1	3	6	9	12	15	18	21	24	27	Means
					TSS (Brix)						
1%CMC	7.20	10.41	8.80	10.30	9.90	9.97	10.67		9.20	9.30	9.27
1%CMC1mLMO	7.20	9.98	9.67	9.83	10.63	10.13	9.13	8.47	8.70	*	9.95
1%CMC3mLMO	7.20	9.77	9.06	9.80	9.03	9.53	8.77	10.57	9.15	*	9.46
1%CMC1mLNO	7.20	9.96	10.17	10.70	10.20	9.70	10.07	9.53	10.20	*	9.47
1%CMC3mLNO	7.20	11.04	9.17	10.23	10.60	9.73	9.97	8.73	10.70	*	9.26
1%MO	7.20	10.82	10.55	10.70	10.50	10.45	10.60	9.85	9.50	*	9.96
3%MO	7.20	10.35	9.70	11.40	8.20	10.90	9.10	9.55	8.40	*	8.7
1%NO	7.20	10.58	10.85	10.80	10.35	9.70	8.55	*	*	*	10.46
3%NO	7.20	10.25	9.70	10.40	10.50	10.20	10.80	11.10	*	*	9.36
0.3%Pro	7.20	9.15	8.10	10.60	10.90	10.05	11.50	11.00	8.90	9.30	9.97
CTRL	7.20	10.36	9.70	10.67	10.47	10.73	12.87	9.53	11.50	*	11.09
Means	7.2		10.26		10.1		10.73		10.15	9.89	

LSD's (0.05) Coating = 0.66 Days = 0.55 Coatings*Days =1.98

	Coatings	Days of storage 1	3	6 Vit C mg/ml	9	12	15	Means
Ambient	1%CMC	2.71	3.37	4.03	4.38	5.14	5.75	4.23
	1%CMC1mLMO	2.71	3.64	4.98	5.66	*	*	4.25
	1%CMC3mLMO	2.71	3.87	5.29	5.29	*	*	3.96
	1%CMC1mLNO	2.71	3.55	4.55	4.73	5.57	5.99	4.52
	1%CMC3mLNO	2.71	3.71	4.87	5.51	*	*	4.20
	1%MO	2.71	3.64	4.11	4.45	*	*	3.73
	3%MO	2.71	3.79	4.32	4.85	*	*	3.92
	1%NO	2.71	3.71	3.92	4.26	*	*	3.65
	3%NO	2.71	3.57	3.67	*	*	*	3.32
	0.3%Pro	2.71	2.97	3.68	4.04	3.77	*	3.43
	CTRL	2.71	2.76	2.53	3.06	*	*	2.77

Cold	1%CMC	2.714	3.27	3.36	4.11	4.50	5.12	3.85
	1%CMC1mLMO	2.71	3.79	3.95	4.49	5.02	5.19	4.19
	1%CMC3mLMO	2.71	4.06	4.50	4.95	5.24	5.19	4.44
	1%CMC1mLNO	2.71	3.60	3.86	4.57	5.10	5.24	4.18
	1%CMC3mLNO	2.71	3.33	4.11	4.31	5.17	5.29	4.15
	1%MO	2.71	3.62	3.75	3.39	5.25	5.00	3.95
	3%MO	2.71	3.53	3.57	3.14	5.25	4.96	3.86
	1%NO	2.71	3.47	3.54	3.29	5.1	5.00	3.85
	3%NO	2.71	3.43	3.44	3.50	3.19	5.25	3.59
	0.3%Pro	2.71	3.11	3.36	3.32	5.11	2.79	3.40
	CTRL	2.71	2.95	3.01	3.21	3.19	3.17	3.04
MEANS		2.71	3.49	3.93	4.16	4.76	4.92	
LSD (0.05)		Coatings =0.1	Days=0.06	Coating*Days= 0.23				

	Days of storage										
	1	3	6	9	12	15	18	21	24	27	Means
						Vit.C mg/ml					
Coatings											

1%CMC	2.71	3.27	3.36	4.11	4.50	5.12	3.04	3.04	2.71	2.40	3.43
1%CMC1MO	2.71	3.79	3.95	4.49	5.02	5.19	3.07	3.07	2.90	*	3.80
1%CMC3MO	2.71	4.06	4.50	4.95	5.24	5.19	2.93	2.93	2.86	*	3.93
1%CMC1mLNO	2.71	3.60	3.86	4.57	5.10	5.24	2.90	2.98	2.21	*	3.68
1%CMC3Mlno	2.71	3.33	4.11	4.31	5.17	5.29	3.11	3.12	3.14	*	3.81
1%MO	2.71	3.62	3.75	3.39	5.25	5.00	3.21	3.25	3.25	*	3.72
3%MO	2.71	3.53	3.57	3.14	5.25	4.96	3.11	3.00	3.11	*	3.60
1%NO	2.71	3.47	3.54	3.29	5.1	5.00	3.29	3.29	*	*	3.7
3%NO	2.71	3.43	3.44	3.50	3.19	5.25	5.12	3.32	3.3	*	3.70
0.3%Pro	2.71	3.11	3.36	3.32	5.11	2.79	2.79	2.75	4.77	2.80	3.35
CTRL	2.71	2.95	3.01	3.21	3.19	3.17	2.90	2.90	2.40	*	2.95
MEANS	2.71	3.46	3.68	3.84	4.74	4.74	3.22	3.06	3.07	2.6	
LSD's (0.05)		Coatings= 0.10				Days=0.09			Coating*Days=0.30		

	Coatings	Days of storage 1	3	6	9	12	15	Means
Ambient	1%CMC	5.29	5.34	5.4	5.76	5.34	5.14	5.38
	1%CMC1mLMO	5.29	5.45	5.35	5.67	*	*	5.44
	1%CMC3mLMO	5.29	5.59	5.59	5.72	*	*	5.53
	1%CMC1mLNO	5.29	5.28	5.4	5.45	5.34	5.25	5.33
	1%CMC3mLNO	5.29	5.31	5.45	5.88	*	*	5.48
	1%MO	5.29	5.27	5.39	5.527	*	*	5.37
	3%MO	5.29	5.43	5.28	5.42	*	*	5.35
	1%NO	5.29	5.23	5.31	5.52	*	*	5.36
	3%NO	5.29	5.42	5.42	5.42	*	*	5.38
	0.3%Pro	5.29	5.3	5.33	5.73	5.33	5.29	5.38
	CTRL	5.29	5.25	4.25	5.63	*	*	5.105
Cold	1%CMC	5.29	5.19	5.24	5.35	5.53	5.57	5.56
	1%CMC1mLMO	5.29	5.3	5.13	5.41	5.52	5.66	5.6
	1%CMC3mLMO	5.29	5.73	5.06	5.48	5.29	5.42	5.6
	1%CMC1mLNO	5.29	5.13	5.28	5.37	5.59	5.58	5.52
	1%CMC3mLNO	5.29	5.2	5.37	5.43	5.52	5.31	5.9
	1%MO	5.29	5.08	5.11	5.33	5.62	5.61	5.5
	3%MO	5.29	5.12	5.18	5.53	5.57	5.47	5.51
	1%NO	5.29	4.96	5.33	5.4	5.56	5.63	5.6
	3%NO	5.29	4.96	5.18	5.45	5.56	5.63	5.58
	0.3%Pro	5.29	5.03	5.41	5.5	5.32	5.58	5.6
	CTRL	5.29	4.47	5.37	5.2	4.28	4.67	4.88

MEANS	5.29	5.23	5.27	5.51	5.38	5.42
LSD’s (0.05)		Coatings = 0.142		Days = 0.01	Coating*Days = 0.34	

Coatings	Days of storage										
	1	3	6	9	12	15	18	21	24	27	Mea
					pH						
1%CMC	5.29	5.19	5.24	5.35	5.53	5.57	5.74	6.16	5.74	5.82	5.56
1%CMC1mLMO	5.29	5.3	5.13	5.41	5.52	5.66	5.77	6.33	5.49	*	5.55
1%CMC3mLMO	5.29	5.73	5.06	5.48	5.29	5.42	5.75	6.39	5.66	*	6.07
1%CMC1mLNO	5.29	5.13	5.28	5.37	5.59	5.58	5.37	6.22	6.06	*	5.54
1%CMC3mLNO	5.29	5.2	5.37	5.43	5.52	5.31	5.8	6.33	5.4	*	5.52
1%MO	5.29	5.08	5.11	5.33	5.62	5.61	5.69	5.97	6	*	5.52
3%MO	5.29	5.12	5.18	5.53	5.57	5.47	5.41	6.19	5.76	*	5.5
1%NO	5.29	4.96	5.33	5.4	5.56	5.63	5.7	6.27	*	*	5.52
3%NO	5.29	4.96	5.18	5.45	5.56	5.63	5.7	6.25	*	*	5.5
0.3%Pro	5.29	5.03	5.41	5.5	5.32	5.58	5.56	6.24	5.84	5.8	5.56
CTRL	5.29	4.47	5.37	5.2	4.28	4.67	4.85	6.13	4.01	*	4.91

MEANS	5.29	5.11	5.24	5.40	5.40	5.47	5.58	6.23	5.55	5.81
LSD's (0.05)	Coatings= 0.0593	Days= 0.04566	Coating*Days=0.1627							

		Days of storage						
		1	3	6	9	12	15	Means
	Coatings			TTA				
Ambient	1%CMC	0.03	0.2	0.32	0.17	0.04	0.05	0.14
	1%CMC1mLMO	0.03	0.2	0.19	0.07	*	*	0.12
	1%CMC3mLMO	0.03	0.21	0.18	0.16	*	*	0.14
	1%CMC1mLNO	0.03	0.16	0.22	0.09	0.07	0.06	0.11

	1%CMC3mLNO	0.03	0.22	0.27	0.06	*	*	0.15
	1%MO	0.03	0.32	0.29	0.11	*	*	0.19
	3%MO	0.03	0.27	1.7	0.08	*	*	0.52
	1%NO	0.03	0.13	0.2	0.16	*	*	0.13
	3%NO	0.03	0.22	0.13	0.11	*	*	0.12
	0.3%Pro	0.03	0.12	0.11	0.16	0.08	0.13	0.1
	CTRL	0.03	0.11	0.12	0.11	*	*	0.416
Cold	1%CMC	0.03	0.12	1.55	0.24	0.14	0.06	0.36
	1%CMC1mLMO	0.03	0.17	0.05	0.26	0.13	0.04	0.12
	1%CMC3mLMO	0.03	0.52	0.07	0.26	0.18	0.06	0.19
	1%CMC1mLNO	0.03	0.15	0.06	0.26	0.14	0.04	0.11
	1%CMC3mLNO	0.03	0.2	0.05	0.26	0.16	0.05	0.12
	1%MO	0.03	0.16	0.05	0.27	0.16	0.06	0.12
	3%MO	0.03	0.06	0.06	0.29	0.16	0.05	0.11
	1%NO	0.03	1.14	0.06	0.29	0.17	0.04	0.29
	3%NO	0.03	0.21	0.05	0.25	0.16	0.05	0.13
	0.3%Pro	0.03	0.21	0.21	0.26	0.15	0.06	0.15
	CTRL	0.03	0.05	0.07	0.25	0.15	0.04	0.1
MEANS		0.03	0.23	0.28	0.2	0.14	0.06	

LSD's (0.05) Coatings= 0.20 Days= 0.13 Coating*Days= 0.46

Days of storage

Coatings	1	3	6	9	12	15	18	21	24	27	Means
						TTA					
1%CMC	0.03	0.12	1.55	0.2424	0.14	0.06	0.08	0.05	0.02	0.10	0.23
1%CMC1mLMO	0.03	0.17	0.05	0.27	0.13	0.04	0.06	0.04	0.04	*	0.10
1%CMC3mLMO	0.03	0.52	0.07	0.26	0.18	0.06	0.08	0.05	0.04	*	0.14
1%CMC1mLNO	0.03	0.15	0.06	0.26	0.14	0.04	0.04	0.04	0.02	*	0.09
1%CMC3mLNO	0.03	0.20	0.05	0.26	0.16	0.05	0.06	0.03	0.04	*	0.10
1%MO	0.03	0.16	0.05	0.27	0.16	0.06	0.08	0.08	0.05	*	0.10
3%MO	0.03	0.06	0.06	0.29	0.16	0.06	0.06	0.07	0.04	*	0.10
1%NO	0.03	1.14	0.06	0.29	0.17	0.04	0.10	0.0553	*	*	0.23
3%NO	0.03	0.21	0.05	0.25	0.16	0.05	0.07	0.030	*	*	0.11
0.3%Pro	0.03	0.21	0.21	0.26	0.15	0.06	0.07	0.04	0.06	*	0.12
CTRL	0.03	0.05	0.07	0.25	0.15	0.04	0.05	0.05	0.08	0.29	0.10

MEANS	0.03	0.2 7	0.2 1	0.27	0.16	0.05	0.07	0.05	0.04	0.19
LSD's (0.05)		Coatings= 0.08				Days= 0.07		Coating*Days=0.25		