UNIVERSITY OF GHANA

COLLEGE OF BASIC AND APPLIED SCIENCES

ENHANCING THE QUALITY CHARACTERISTICS OF PLANTAIN (*Apantu*) THROUGH DIFFERENT POSTHARVEST TREATMENTS

BY

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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MPHIL NUTRITION AND FOOD SCIENCE DEGREE.

JULY, 2017

DECLARATION

This is to certify that this thesis is the result of research undertaken by Nicholas Frank Quarshie towards the award of the Master of Philosophy in Food Science in the Department of Nutrition and Food Science, University of Ghana.

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DEDICATION

This work is dedicated to the Glory of the Almighty God.

ACKNOWLEDGEMENTS

My greatest thanks and appreciation goes to the Almighty God for His love, protection, provision, grace and mercy throughout this course. I wonder how my life would have been without Him.

I am also eternally grateful to all my three supervisors, Prof. Agnes Simpson Budu, Prof. Firibu Kwesi Saalia and especially, Prof. Esther Sakyi-Dawson, who dedicated time off their extremely busy schedules to go through the manuscripts and made salient contributions, comments and corrections which fine-tuned, and refined this work. To Prof. Esther Sakyi-Dawson I say, Mummy, you are more than just a lecturer to me that is the reason why I chose to call you Mummy always, God bless you abundantly for your kindness.

My sincere thanks also goes to Mrs. Joyce Duah, Senior Laboratory Technician at the Department of Nutrition and Food Science, UG, for her immense help which sometimes included staying in the laboratory with me way beyond normal working hours.

To my family, friends and course mates, thank you all for your support and love.

ABSTRACT

Plantain production in Ghana is bedeviled with some postharvest problems despite the fact that it is an important subsistence and cash crop for small scale rural producers. These postharvest problems affect quality of plantain offered on the market and increase losses. Generally, because plantain handlers are reluctant to bear extra costs during the postharvest activities, interventions to reduce the postharvest problems of plantain must take into consideration cost. This study was conducted to improve the quality of plantain during the postharvest handling period using of different postharvest methods and treatments. The study was sectioned into two parts. The first part was a survey conducted to evaluate the postharvest handling practices of plantain and the difficulties involved during the handling chain. Fifty (50) plantain handlers at Agbogbloshie, Madina, Dome and Texpo markets in the Accra Metropolis and Adeiso market in the Eastern region were the respondents. The major postharvest problems encountered by these respondents were; Distribution/Transportation (24%), Delaying Ripening (20%), Storage facilities (18%), Packaging (16%), Hastening ripening (14%), Finance (6%) and Others (2%).

The experimental part of the study involved using locally available and affordable postharvest methods and treatments to improve on some of the postharvest problems identified during the survey. Plantains transported in wooden box with plantain leaves lining or polyethylene lining and plastic basket with plantain leaves lining, polyethylene lining or no lining as well as paper carton with plantain leaves lining, polyethylene lining or no lining significantly reduced bruises and reduced peel/pulp softening at 5% probability level than transporting without packaging. As determined by the peel color, pulp firmness, titratable acidity, total soluble solids, reducing sugar and starch content monitored for 8 days, the black polyethylene bag proved a better storage material by significantly preserving the quality and extending the green life of plantain for 192

hours while ripening proceeded faster in the blue polyethylene bag than the black, yellow, transparent, white polyethylene bags and the control. The use of shredded and moistened plantain pseudo stem wrapped in polyethylene sheet as a storage material for plantain preserved the freshness quality and increased the green life of plantain from 4-7 to 16 days but when $KMnO_4$ was added, the green life was shortened and ripening begun after 8 days. Corn dough alone as a treatment could not induce ripening in plantain within 24 hours as measured by peel color (1.67), titratable acidity (0.28), total soluble solids (8.00), starch content (3.83) and reducing sugars (0.57) but ripening was achieved within 24 hours in all samples of plantain where CaC_2 was used as a treatment due to the generation of acetylene gas. Consequently, wooden box, plastic basket and paper packaging with either leaves or polyethylene sheet lining could be promoted as locally available and low cost transportation materials as well as using the black polyethylene bag and/or shredded plantain pseudo stem as a storage material to extend the green life of plantain. Patrons of ripe plantain should also watch out when they are buying from the market since some of the market women are still using the banned calcium carbide to ripen the plantain.

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1.0 INTRODUCTION

1.1 General Issues with Plantain Production in Ghana

In the ranking for plantain production, Ghana ranks third to Uganda and Cameroon who occupy the first and the second positions respectively in the world ranking (FAOSTAT, 2014). The national production of plantain in Ghana increased from 1.1 metric tons in 1992 to about 3.6 million metric tons per annum in 2005 and to about 3.8 million metric tons in 2014. In Ghana, plantain is also highly ranked in terms of food preference, it makes about 13.1 per cent contribution to the Agricultural Gross Domestic product (AGDP) with a current per capita consumption of about 84 kg per head, and out of this figure, about 90 per cent is consumed locally (SRID-MOFA, 2014; FAOSTAT, 2014).

Bulk cultivation of plantain in Ghana has been concentrated in smallholder farms in either mixed cropping or monoculture systems as well as backyard farms in the rural areas of Western, Central, Brong Ahafo, Ashanti and the Eastern regions. In some mixed cropping systems farmers use it mainly as a shade for cocoa seedlings, but plantain cultivation is also a source of rural income and food. The regions where the crop is grown span over three main agro-ecological zones of the rain forest, moist semi-deciduous forest and the forest-savanna transition with a cultivated land area that covers about 359,865 hectares of Ghana's agricultural land (SRID-MOFA, 2010; Akinyemi *et al.*, 2010).

The False Horn plantain (with local names; Apantu, Apentu pa, Brodewuo, Osoboaso or Brode sebo) is the most popular variety of plantain in Ghana in terms of cultivation and consumption as compared to other cultivars like the French Horn (also known locally as Apem, Oniaba, Apempa or Nyeretia) and the True Horn (Asamienu or Aowin). Production of the crop has been identified to be of a significant importance to the economy of Ghana contributing to food security and job creation especially the non-traditional sector of the rural economy (Dzomeku *et al.*, 2016; Ayanwale *et al.*, 2016). Its consumption also cuts across many cultures and homes in Ghana where both the unripe and the ripe fruits are used in the preparation of several local delicacies like; *'fufu', 'ampesi', 'etor', 'red red', 'kelewele', 'tatale', 'kakro', 'Kofi broke man' (roasted), plantain chips* and many others. The many kinds of food prepared from plantain tell of its versatility, preference and the importance of the crop in ensuring national food security.

Usually, the period when plantain is abundant on the local markets is from September to March, with the glut period between November and February, (Adewunmi *et al*, 2009; Akinyemi *et al.*, 2010). In 2016, the five-month scarcity period (April-August) for plantain was abnormally cruel in Ghana due to the prolonged dry season and the strong winds which accompanied the commencement of the rainy season. This led to acute shortages and compelled some local dealers to travel to as far as neighboring Ivory Coast and Burkina Faso to purchase the crop which also in turn surged the price of plantain on the local markets (preliminary study revealed).

Due to the dispersed nature of the production centers, middlemen and market queens play a pivotal role in the assembling, distribution and sale of plantain on the local markets. Four major channels for the distribution of the crop are currently identified according to Dzomeku *et al.* (2011). These are: from producer to wholesaler to retailer; producer to wholesaler to retailer to agri-industry and from producer directly to agri-industry. These trends, also exacerbated by the poor nature of the road networks leading to the production zones make the marketing of plantain quite a grueling one. On the Ghanaian market, there is currently no proper form of packaging for plantain as well as during transportation. During transit, bunches are packed directly into the trucks in stacks or sometimes separated into single fingers and packed in either jute or used fertilizer sacks before stacking them in the trucks. As a result, bruises, breakages, peel darkening and all kinds of damages during on-loading, transit, off-loading and storage become inevitable. These also predispose the plantain to postharvest losses and fungal diseases such as crown rot, anthracnose, cigar-end rot and finger rot (Dadzie and Orchard, 1997).

1.2 Study Rationale

A research conducted on the postharvest losses in 11 African countries discovered that about 50-60% of all food crops produced in Ghana do not make it to the final consumer (AGRA, 2014). Annual postharvest losses of plantain in developing countries have been reported to range from 10% to as high as 35% (Sugri *et al.,* 2010; Odemero, 2013). These losses have been attributed to poor handling practices in the value chain of plantain (Adeniji *et al*., 2010).

Dzormeku *et al.* (2016) also reported that, despite the significant role played by plantain in the farming systems in Ghana, no conscious effort has been made to develop any proper and reliable pre-harvest and postharvest indices for local farmers to use.

A preliminary survey undertaken between September and November 2016 as part of this study revealed that, plantain handlers at the various market centers did not have any reliable means of either hastening ripening or delaying it once it sets in, apart from relying on natural processes. It was observed that a section of the market women at Agbogbloshie market in Accra were forced to resort to the use of corn dough to induce ripening in plantain, an indigenous technology which was yet to be verified. Others also admitted to using calcium carbide, a chemical found to be injurious and hazardous to human health (Wasim and Dhua, 2010; Suman *et al*., 2011). These indigenous methods and many others yet to come to light but already in use, if not verified could be a source of potential danger to consumers. It is against this background that this study was conducted to come up with cheap and locally adoptable alternative means of packaging for plantain and also, how to either delay or hasten ripening of plantain when required, in order to improve on the quality and reduce postharvest losses.

1.3 Research Questions

The questions this research sought to find answers to were;

i) What are the major problems in the postharvest handling of plantain?

ii) At what stage of the handling chain do these problems occur?

iii) What ways and to what extent do they affect the produce?

iv) What innovative ways could these identified problems be tackled?

v) Are there alternatively cheaper and locally available materials or methods that could be used to address these problems?

vi) How easy would it be for the plantain handlers to adopt these methods or materials?

1.4 Study Objectives

The main objective of the study was to improve the quality of plantain offered to consumers on the local markets and reduce postharvest losses in plantain to the barest minimum.

The specific objectives were;

1. To evaluate the postharvest handling practices for plantain on the local markets.

2. To investigate the effect of different forms of packaging used in transporting plantain on the quality of plantain.

3. To evaluate the effects of different colors of polyethylene sheets on the ripening behavior and postharvest shelf life of plantain.

4. To evaluate the use of shredded plantain pseudo-stem as a preservation material for plantain after harvest.

5. To determine the effects of Calcium carbide (CaC_2) and corn dough on the ripening behavior of plantain.

2.0 LITERATURE REVIEW

2.1 Origin and Center of Domestication

'Bananas', the general term used to embrace all the cultivated varieties in the genus *Musa* that belong to either one of the two sub-groups (Pillay *et al.*, 2004), whiles a specific sub-group in the cooking bananas are given the term 'plantain' (Valmayor *et al.*, 2000). The name 'banana' is supposed to have immerged in Guinea, West Africa during the introduction of the crop by the Portuguese, from where it spread to other parts of the world (Cheesman, 1948). It is also believed to have originated from an Arabic root word *'banan'*, which means finger (Boning, 2006).

According to Simmonds and Shepherd (1955), although the exact origin of the present day edible bananas is not known, there is a widespread believe that the primary center of origin is a certain biogeographical region called Malesia which includes; Indonesia, New Guinea, Malay Peninsula and the Philippines with India as its secondary center. Daniells *et al.* (2001) also reported the likelihood of human movement being the sole cause of the crop's dispersal to the other parts of the world.

Present edible bananas have resulted from a mixture of both wild and cultivated species and hybrids linked to *Musa accuminata* and *Musa balbisiana* with Asia, specifically Malaysia (Simmonds 1962) and Indonesia (Horry *et al.*, 1997) believed to be the center of diversity for the *M. accuminata*, the most common specie of the genus *Musa* (Daniells *et al.*, 2001).

Plantain cultivation is reported to have started in West and East African regions some 3,000 years ago where they were initially propagated for their fresh fibers and starchy corms and not the fruits. These two regions in Africa are therefore thought of as the two main secondary centers for the diversity of *Musa* (De Langhe, 1995). Bananas are considered to be one of the earliest crops domesticated by man with reference dating back to as early as 500 BC (De Langhe, 1995). Trading of the crop started with the Arabian, Persian, Indonesian and Indian traders who distributed the suckers around certain areas of the Indian Ocean around the 5th to 15th centuries, and today the cultivation of the crop is seen mostly in the tropics and sub-tropics specifically, West and East Africa, South America, Asia and Australia (Ploetz *et al.*, 2007).

2.2 Classification of Plantain and Banana

According to Simmonds (1966), modern classification of bananas put edible plantains and banana in the family Musaceae. The family includes two main genera *Musa* and *Ensete* and sometimes the monotypic genus, *Musella* (Constantine and Rossel, 2001).

The genus *Ensete* has about nine species which are predominant in Southern Asia and Africa, and species in this genus are mostly ornamentals with fruits similar to that of banana but only that they have seedy, dry, inedible fruits and also the entire plant normally dies after fruiting (Ploetz *et al.*, 2007).

Musa, formerly *Eumusa* (Wong *et al.*, 2002), has a great number of important plants bearing edible fruit that includes bananas and plantains. Eating bananas are believed to be interspecific hybrids of two wild species *Musa acuminata* and *Musa balbisiana* (Ploetz *et al.*, 2007). There seem to be some level of confusion about the *Musa* taxonomy (Constantine, 2004) which has led to the persistent adoption of Linnaeus' work in *System Naturae* where he designated *M. paradisiaca* to 'French plantain' and *M. sapientum* to 'Silk' (similar to dessert banana) even decades after recognizing that the cultivars to which these names were referred to are hybrids of

M. accuminata and *M. balbisiana* (Constantine and Rossel, 2001). This led to the proposal of genome nomenclature by Simmonds and Sherpherd (1995) which was subsequently revised in 1987 (Silayoi and Chomchalow, 1995). That notwithstanding, four historical sections are presently recognized in the *Musa* genus as; Callimusa, Australimusa, Rhodochlamys and Musa (Ploetz *et al.*, 2007)

2.3 Economic Importance of Bananas and Plantains in the Food Chain

Plantain occupies a strategic position in the world food production such that, it has been rated the fourth most important food crop after rice, wheat and maize (Phillip *et al.*, 2009; FAO, 2014). It is a major staple food and also a cash crop supporting the socio-cultural life of both rural and urban economies in sub-Saharan Africa (IITA, 2009). In Ghana and Nigeria, the crop is the third most important starchy staple after yam and cassava (FAO, 2014). The socioeconomic importance of plantain and banana in most African economies where it is cultivated is seen in the areas of job creation, food security and as a source of rural income. Also, in Ghana only a hectare of plantain cultivation is said to provide an average of 0.75 direct employments which when compared with the national cultivated acreage, transmits into about 350,523 permanent jobs for people (Rodriguez and Rodriguez, 2001, Dzomeku *et al.*, 2011).

Apart from being used as food, it has been found to possess a proven medical and an outstanding industrial relevance (Faturoti *et al*., 2007). The low sodium content in plantain makes it an ideal diet for people with kidney diseases and also, its ability to neutralize free hydrochloric acid makes it a very potent medicine for treating peptic ulcer, especially the peels (Gowen, 1995)

Plantain has also been described as a multipurpose crop with a great potential of being processed into different products. As result, several processing industries have crop up processing the crop into products like cakes, biscuits and bread (Ogazi, 1996; Phillip *et al*., 2009). In many homes, it is the raw material for the preparation of several popular local delicacies and snacks (Aina *et al*., 2012). For example, in Cameroun, Ghana, Nigeria and other parts of Africa, the plantain may be boiled, fried, roasted and sometimes even baked into different kinds of food products with some of the methods requiring further processing like slicing/cutting, mashing and grinding. The crop is also said to be a major source of carbohydrates for many people in Latin America, the Pacific, Asia, the Caribbean and Africa (Tchango *et al*., 1999).

2.4 World production of plantain

Plantains and bananas are known to be cultivated in about 120 countries in the world (Olorunda, 2000) with the estimated total world production of plantains presently around 33 million metric tons. Out of the total production, about 32% or more is produced in West Africa alone (FAOSTAT, 2014). According to the same statistics, the top ten countries are from Africa and the Caribbean regions with the top three on the chat being Uganda, Cameroun and Ghana (all African countries) producing 4.6 million MT, 3.9 million MT and 3.8 million MT respectively. Nigeria is 5th and Cote d'Ivoire is 7th producing 3.0 million MT and 1.6 million MT respectively. These statistics emphasizes the importance of sub-Saharan Africa, particularly West Africa in the worldwide production of plantain (EPAR, 2013). Available Food and Agricultural Organization Statistics (FAOSTAT) over the years also show that plantain production in Africa is much higher as compared to banana production.

In Ghana, plantain cultivation covers about 337, 000 hectares of the available farm lands with an average farm size of around 0.8 hectares. The total household farming of plantain in Ghana is also estimated to be over 400,000 with over more than 90% of the cultivated area in small holder farms (SRID-MOFA, 2014). Plantain together with maize, rice, sorghum, millet, cowpea, cassava, yam and cocoyam are the major food crops known to be cultivated in Ghana which together contribute appreciably to the country's Agricultural Gross Domestic Products (AGRA, 2014).

2.5 Postharvest Losses in Fresh Produce

Postharvest losses have been variously defined by many authors (Parfitt *et al.*, 2010). Generally, all the definitions for 'postharvest losses' have revolved around anything or any condition that causes quantitative and/or qualitative decrease in the produce during the various interconnected activities from harvesting through to the final consumer that are measurable (Kader, 2002, Grolleaud, 2002; Stuart, 2009). Qualitative loss which includes the acceptability or edibility and/or loss in nutrient content of a given food product are more common among developed countries (Kader, 2002) while quantitative loss that result from loss in amount of products are much common in developing countries (Kintinoja and Gorny, 1999).

The issue of food loss may be confused with food damage and food wastage. Food damage refers to any physical sign of deterioration that constrains the use of the product/food but Food loss as defined earlier, is when the product/food becomes impossible or unavailable to be used (ACF, 2014). In fresh agricultural produce like fruits, vegetables and tubers, these losses may occur as a result of certain natural or biochemical changes and processes that go on even after harvest (Sousa-Gallagher *et al.*, 2011). The preliminary study conducted showed that the incidence of food damage is high in plantain postharvest handling than compared to food loss, even though in some few instances losses are recorded.

Food waste on the other hand is when food appropriate for human consumption is left to spoil or discarded whether before or after its expiry date (ACF, 2014). Wastage therefore results from the behavior of consumers and food handlers, and the term "wastage" is used to include loss and waste of food. This definition however, does not include inedible parts of food dispose of or animal feed but rather, a subset of food loss which can be retrieved for human consumption (Hodges *et al.*, 2011).

A careful look at the nature of losses recorded in plantain after harvest depicts that food wastage is infinitesimally low for plantain in sub-Saharan Africa because of the many uses found for plantain in this region (Ogazi, 1996; Phillip *et al.*, 2009). For example, in Ghana, plantains are used in the preparation of several dishes right from the matured green stage to when it is overripe, and even when it is almost rotten it is used to prepare '*tatale*', a local dish in Ghana prepared by using overripe plantain. Therefore, plantain is barely wasted due to its many uses. However, whether it is a food damage, food waste or food loss, research has shown that they are all likely to occur at any stage in the postharvest chain and sometimes even at the production stage (Parfitt *et al.*, 2010).

2.6 Estimated Postharvest Losses of Plantain

The global estimation of loss in all foods produced is about 1.3 billion tons (Parfitt *et al.*, 2010). The problem of loss seems to be enormous in parts of Africa, the Pacific and the Caribbean (ACP countries), where about 40-50% of the total of fresh produce from these regions are wasted due to poorly developed infrastructure and further worsened by the tropical weather (SPORE, 2011).

Postharvest loss in plantain alone in the developing countries is estimated to be around 35% (Adeniji *et al.*, 2010). It is estimated to be as high as 40% in Nigeria (Odemero, 2013) and about 10-30% in Ghana annually (Sugri and Johnson, 2009). Also, AGRA (2014) report stated that 50-60% of all food crops grown in Ghana fail to make it to the final consumer. These high postharvest losses and wastes recorded in plantain (and other fresh produce) are a major factor that limits the availability of crop on the market (Ayanwale *et al.*, 2016).

Globally, food wastage and/or losses are higher in the downstream phases of the food chain in high-income countries whereas more wastage and loss are recorded at the upstream phases in low-income regions (FAO, 2013). The population of the world in 2050 is expected to rise to about 9 billion and by this figure, there must be a corresponding rise of about 70% in the world's food production of especially the major food crops in order to be able to feed this population (FAO, 2011). These high postharvest losses recorded in fresh produce especially, in Africa could therefore be tolerated no longer and as such diverse interventions and strategies are required (ACF, 2014).

2.7 Shelf Life of Fresh Produce

The length of time within which a given fresh produce can maintain an accepted level of quality preferred by the consumer when kept under certain stated conditions is referred to as its shelf life (Sousa-Gallagher and Mahajan, 2011). Shelf life period could also extend from the time of harvesting all the way to the start of rotting of fruits (Dadzie and Orchard, 1997). In the case of bananas and plantain, it could refer to either from the time period between the time of harvest (at harvest or physiological maturity) and the end of the green life (commencement of ripening) or the period from harvest/initiation of ripening to the end of edible or saleable life, depending on the usage (Dadzie and Orchard, 1997).

In a classical work by John and Marchal (1995) and Robinson (1996) three physiological phases have been determined in the postharvest life of bananas and plantains. These phases are; pre-climacteric phase/stage, climacteric phase/stage and senescence. The pre-climacteric phase (unripe stage) is the time right after harvest when the fruit is firm and green with a very low respiration rate and ethylene production. The climacteric stage (ripening phase) is characterized by increased ethylene production and increased respiration rate leading diverse biochemical, physiological and compositional changes in the fruit. Following right after this stage/phase is the senescence or the ageing period where almost all the sugar and acid reserves have been used as respiratory substrates and consequently respiration rate decreases and deterioration commences if the process is not intercepted. Sugri and Johnson (2009) asserted that the use of appropriate methods of storage could extend the pre-climacteric phase and delay the commencement of the climacteric phase where there seem to be a rise in most of the deleterious activities within fruits.

Strategies to extend the shelf life and/or preserve the quality of fresh fruits and vegetables have never been an easy task due to their high perishability (Wu *et al.*, 2012). This is because many factors have the ability to cause the loss of their quality and stability, hence their name `perishables' (Sousa-Gallagher and Mahajan, 2011). As living tissues, normal processes like respiration and transpiration continue and once they are separated from their mother plant, important factors like nutrients, source of water and anti-ageing hormones are deprived, therefore, deterioration becomes faster if not controlled (Sousa-Gallagher and Mahajan, 2011).

Their perishability or short shelf life is further worsened when there is a disruption of the compact tissue structure or cell integrity because this predisposes them to microbial attacks and high respiratory activities (Olusola, 2002). Prevention of mechanical damages and microbial infections can therefore help extend the shelf life of the produce but not for a longer period if other factors of deterioration are not controlled (Mahajan, 2002). Generally, bananas and plantain are considered highly perishable because under normal atmospheric conditions they ripen within 2 to 7 days when harvested at the matured green stage and also deteriorate within about a week or two after initiation of ripening (Robinson, 1996; Daniells, 2003).

From the producer's/distributor's point of view, one vital quality of fruits and vegetables during the holding period is the shelf life, since it allows for a decision on the expected risk and how to maintain commercial value (Radajewska and Borowiak, 2002). Several strategies and methods with the ability to extend the shelf life of fruits and vegetables have been used over the years, and some of these strategies are; modified atmosphere package (MAP) and controlled atmosphere (CA) (Sousa-Gallagher and Mahajan, 2011), cold/low temperature storage, edible coatings and anti-browning dipping (Albanese *et al.*, 2007), and use of ethylene absorbents (Chaves *et al.*, 2007; Silva *et al.*, 2009). Some of these methods are indigenous whereas others are quite cosmopolitan. For example, the use of sawdust to extend the shelf life of plantain in some rural areas of Cameroun has been reported by Tchango *et al.* (1999), and Sugri and Johnson (2009). Cassava starch coating delaying change in color and prolonging the storage life of freshly cut pineapples was opined by Nurul (2012) whereas the positive effect of wax coating in extending the shelf life and improving the quality of sweet orange was also reported by Shahid and Abbasi (2011).

2.7.1 Respiration of fresh produce

Respiration is the oxidative breakdown of organic substrates to produce carbon dioxide (CO_2), water (H_2O) molecules and energy (Fonseca *et al.*, 2002). It is one of the important processes in fresh produce that affects the quality and shelf life (Fagundes *et al.*, 2013). The substrates consumed during respiration are the sugar and acid reserves with increased metabolism activity, leading to a shortening of their shelf life (Chitarra and Chitarra, 2005). In other words, the respiration rate of a given fresh produce is inversely proportional to its shelf life and therefore, the estimation of respiration rate is of crucial importance in shelf life determination (Kader, 1987).

According to Saltveit (2003) and Rocculi *et al.* (2006), the rate at which fresh produce respire depends on certain external and internal factors. The external factors refer to the conditions in the storage environment such as temperature, gaseous composition, presence/absence of ethylene and relative humidity while the internal factors refer to the nature/type of the fresh produce such as variety, stage of maturity/ripening and extent of bruises/damages. Both also reported the ability to decrease respiration rate of fruits and vegetables up to certain limits when the oxygen gas (O_2) and CO_2 concentrations are decreased and increased respectively. Bananas and plantains under ambient conditions have been reported to have a moderate respiration rate of between 10-20 mg CO_2 kg^{-1} h^{-1} compared to the high rate of between 20 – 40 mg CO_2 kg^{-1} h^{-1} for avocados and low rate of between 5 – 10 mg CO_2 kg^{-1} h^{-1} for apples, citrus, potatoes and onions under same conditions (Kader, 1987).

Based on the distinct respiration rates of fruits and vegetables, they are classified as either climacterics or non-climacterics (Mahajan and Goswami, 1999; Suman *et al.*, 2011). In climacteric fruits there is a trend of decreasing respiration rate to a very low value also known as the pre-climacteric minimum. This is then followed by a sudden upsurge in the rate of respiration to the climacteric peak also termed respiratory climacteric. This respiratory climacteric is that point in time during the development of the fruit when there is a change from growth to senescence due to a series of biochemical changes and an autocatalytic ethylene production initiated by a rise in respiration rate (Sousa-Gallagher and Mahajan, 2011). This process is what makes climacteric fruits to continue to ripen even when harvested matured green from the mother plant. When temperature is not controlled, there is a rapid ripening and senescence in climacteric fruits due the rise in respiration. It also leads to tissues breakdown, synthesis of characteristic volatiles and moisture loss due to the over ripening. Fungal and bacterial infections can also result from high moisture and warmth (Aked, 2000).

Non-climacterics show no rise in respiration rate and there is also no rise in ethylene production (Sousa-Gallagher and Mahajan, 2011). In this kind of fruits, the process of ripening can only be completed when the fruit is on the mother plant (Kader, 2002a). Unlike Climacterics, their eating quality greatly suffers when picked from the parent plant before the ripening process completes since their acid and sugar contents do not increase afterwards (El-ramady *et al.*, 2015). Some examples of both climacterics and non-climacteric fruits according to Kader (2002a) and Sirivatanapa (2006) are listed in Table 2.1.

Table 2.1 Classification of fruits according to their respiratory behavior during ripening.

Non-climacterics	Climacterics
Lime	Guava
Grape	Papaya
Orange	Banana
Pomegranate	Plantain
Pineapple	Pear
Watermelon	Apple
Lemon	Avocado
Blackberry	Berries
Cranberry	Melons
Cherry	Plum
Raspberry	Apricot
Litchi	Kiwifruit

2.8 Ripening in Fruits

Ripening in fruits is simply the ultimate stage of fruit development which involves a number of metabolic, biochemical and physiological changes which causes the fruit to develop key quality attributes like color, texture, aroma, flavor as well as making the fruits sweeter and eatable (Payasi and Sanwal, 2005; Gandhi *et al.*, 2016). There is a breakdown in chlorophyll, and the fruit becomes less green, softer and regardless of the rise in acidity, the fruit still becomes sweeter and attractive to consume (Rahman *et al.*, 2008). Sampaio *et al.* (2007) described the ripening process in fruits as being associated with synthesis of novel proteins, mRNA, flavor and pigments in the fruit by using the carbon skeleton blocks and energy supplied to the tissues through the respiration process. By nature, ripening normally occurs when fruits have attained the right physiological maturity or after the matured green stage telling of an internal genomic control mechanisms and phenomenon that prevent premature fruits from ripening (Clendennen and May, 1997; Seymour *et al.*, 2002).

In a definitive work on bananas and plantains Dadzie and Orchard (1997) showed them to be typical climacteric fruits which experience a sudden exponential increase in respiration rate and subsequent metabolic changes that result in significant transformations in color, texture and flavor during ripening. This rise in respiration rate of ripening fruits has been discovered to quadruple and Sugri and Johnson (2009) cited this to be the main reason responsible for the faster deterioration rate of ripe fruits as compared with green ones.

Certain chemicals have been shown to promote the ripening process of fruits (Suman *et al.*, 2011; Sogo-Temi *et al.*, 2014). These ripening agents may be natural or artificial (Gunasekara *et al.*, 2015). Natural ripening process is known to be controlled by genes which regulates the release of ethylene gas (a natural agent) to initiate the ripening process (Gray *et al.*, 1992).

Artificial ripening on the other hand, is a commercial strategy deployed to reduce the losses during transportation by harvesting fruits prior to the release of ethylene by natural processes at the matured green stage and using artificially prepared chemicals to cause ripening in the harvested fruits later in the handling process when required (Gunasekara *et al.*, 2015). Examples of these commercially known artificial ripening agents are; Ethephone, Ethrel, Ethylene glycol, Artificial ethylene and calcium carbide.

2.8.1 Ethylene gas as a ripening agent

Ethylene (C_2H_4) is a colorless naturally occurring gaseous compound usually produced by plants to regulate growth. It has been found to be responsible for certain developmental and physiological processes during the growth and development of plants such as; loss of chlorophyll and carotene synthesis, conversion of starch, epinasty, increasing the activity of cell wall degrading enzymes, abscission or abortion of plant parts and stem shortening (Gray *et al.*, 1992). This shows that, although it is the main natural gas responsible for ripening, it plays a central role in many plant activities ranging from germination to ageing.

The use of ethylene gas is mainly to induce ripening and coloring of fruits like mangoes, pears, tomatoes, citrus, plantains and bananas whereas it stimulates flowering in pineapples and also improves appearance and growth of bean sprouts when applied on the field using ethylene generator or gas emission systems (Suman *et al.*, 2011). When applied artificially to achieve these purposes, extra care has to be taken since higher concentrations could cause undesirable effects in fruits and vegetables, and can also have bad effects on human health (Hasan *et al.*, 2010).

Also, climacteric and non-climacteric fruits respond differently to ethylene treatments. Treating an immature climacteric fruit with as low as 0.1 to 10 ppm ethylene accelerates climacteric responses and its accompanied ripening changes without any major change in respiratory magnitude but in non-climacterics, the same quantity will lead to a rise in respiration and ethylene production which is not correlated with the inception of ripening (Sousa-Gallagher and Mahajan, 2011).

2.8.2 Calcium carbide (CaC_2) as a ripening a agent

Calcium carbide is a grayish black substance commercially available in either a block or powdered form which is originally used for welding purposes (Suman, *et al.*, 2011). Its ability to produce acetylene gas that functions like ethylene has therefore triggered its use as an artificial ripening agent in fruits. When in use, higher concentrations of acetylene are needed to initiate the ripening process than compared to ethylene. Just like the ethylene gas, the acetylene produced by the calcium carbide when mixed with water is also able to trigger the enzymatic action that breaks down the glucose and causes rapid ripening (Rahman *et al.*, 2008).

Fruits ripened with calcium carbide characteristically develop good peel color but are soft and also have poor flavor (Rahman *et al.*, 2008; Gandhi, 2016). This has resulted in its extensive use on fruits like bananas, papayas, mangoes, apples and plums mostly in the developing countries (Suman *et al.*, 2011).

Despite giving some ripening benefits, the acetylene gas produced by the calcium carbide has been found to affect the neurological system which causes a health condition called prolonged hypoxia (Per *et al.*, 2007). This condition may also result in diseases like dizziness, persistent headaches, mental confusion, sleepiness, mood disturbances, memory loss, cerebral endema and seizure. Usage of calcium carbide on food has also been found to be extremely hazardous and carcinogenic due to the traces of phosphorous and arsenic discovered to be contained in it (Suman *et al.*, 2011). These mentioned dangers made a ban to be placed on its use on food materials by the international rule on the prevention of Food Adulteration Rules (Act 1954 and 1955) (Gunasekara *et al.*, 2015). Regardless of the associated dangers and the ban on the substance, available records indicate that traders still prefer using the calcium carbide than recommended practices due its cheap cost (Suman, *et al.*, 2011).

Other artificial ripening agents which may are potentially toxic substances (Sogo-Temi *et al.*, 2014) such as torch light battery, potash, African mango fruits and leaves, yellow pawpaw leaves, palm nut, cassia leaves and ash as indigenous ripening technologies for banana and plantain in some parts of Africa have also been reported (Ajayi and Mba, 2007; Adewole and Duruji, 2010).

2.9 Ripening of Plantain

Commercial producers through artificial ripening methods are able to achieve ripening in a much faster rate through controlled atmospheres (Rahman *et al.*, 2008). Under these controlled atmospheres, most commercial plantain cultivars require an exposure to as little 100 to 150 ppm of ethylene gas at a temperature of about 15˚C to 20˚C and a relative humidity of 90 to 95% to stimulate uniform ripening in the produce (NARI, 2003). To prevent carbon dioxide from delaying the ethylene action, concentration levels of the CO_2 are kept below l% as in the controlled atmosphere. Temperature regulation is also a very important factor here and must correspond very well with the desired degree of ripening since a temperature higher than 25˚C can make the pulp undesirably soft (Tchango *et al.*, 1999).

Due to the high cost and the difficulty in getting the commonly used ethylene gas in some local communities (Rahman *et al.*, 2008), market women who need to sell their plantains at the ripe state traditionally initiate the process of ripening by piling the plantain in baskets lined with sacks or polyethylene sheets, or in drums and other containers suitable enough to exclude air circulation and accumulate heat around the produce. Sometimes too, they do so by just piling them in heaps on the ground (Tchango *et al.*, 1999) while others too trigger ethylene production or initiate ripening in the heaped produce by adding previously ripe plantain to the pile or stored produce. These methods normally take about 3-7 days or even more depending on the maturity stage of the fruits and other environmental factors like temperature and humidity (Robinson, 1996; Daniells, 2003).

The unavailability of proper ripening techniques for market women to use (Ajayi and Mbah, 2003) has resulted in the use of unapproved methods such as the indiscriminate application of calcium carbide which is intended for welding purposes on fruits, in order to artificially develop the desired fruit color within a short period (Per *et al.*, 2007; Rahman *et al.*, 2008).

2.10 Quality Attributes of Ripening

Fruit quality simply refers to the degree or extent of excellence or superiority of the fruit for a particular purpose which is assessed either qualitatively or quantitatively (Gunasekara *et al.*, 2015). Qualitative assessments are usually achieved through the use of the five sensory attributes whereas quantitative assessments are used for physico-chemical parameters such as; peel to pulp ratio, moisture content, Total Soluble Solids (TSS), Total Titratable Acidity (TA), Total Sugar or Starch and Vitamin C (Dadzie and Orchard, 1997; Gunasekara *et al.*, 2015). During ripening, fruits undergo many complex changes some of which may be physical or chemical which may develop independent of each other and these changes sum up to determine the quality of the fruit.

Due to these changes both internal and external, the orthodox way of determining the degree of ripeness of fruits which have been much dependent on the superficial changes that occur in the peel may not be a reliable one (Dadzie and Orchard, 1997). This is because, there are times when low relative humidity, high temperatures and other genetic factors cause the peel color of the fruits to remain green even when ripening has already occurred internally. Therefore, a combination of external as well as internal changes to determine the maximum eating quality of fruits have become very essential (Wills *et al.*, 1998; Anthon, *et al.*, 2011). Among some of the compositional changes in fruits that are indicative of ripeness are as follows;

2.10.1 Changes in peel color

Change in fruit color is one of the easily noticeable changes that occur in most fruits. As an overall outward appearance of ripeness it is one the most important external qualities that affects consumer's decision on the edibility of a given fruit since it is a reflection of the internal changes in the pulp (Kays, 1999). In some fruits it is not only the peel color that changes but also there is a significant change in the pulp color as well. These changes give an indication on the degree of ripeness and subsequent postharvest life of the fruit (Ajayi and Mbah, 2007). Traditionally, there are accepted colors for fruits that give an indication of unripe, ripe or overripe. The development of these colors in fruits is greatly influenced by certain naturally occurring pigments in the fruit which result from either the degradation of the chlorophyll structure and/or the synthesis of carotenoids (Dadzie and Orchard, 1997). These carotenoids synthesized in plants gives color to fruits and may normally occur as red, orange or yellow pigments.

In bananas and plantains, the break in the green color and the appearance of the yellow color which is indicative of ripening usually commences immediately after the climacteric peak in about two to seven days after harvest, depending on the fruit maturity and the temperature (Wills *et al.*, 1998; Ajayi and Mbah 2007). The conventional way of determining the degree of ripeness of in fruits have been much dependent peel color and so quick assessments of the degree of ripeness of fruits are usually done by comparing the changes in the peel color with standard color charts (Dadzie and Orchard, 1997). Colorimeters are also used in some cases.

2.10.2 Changes in fruit firmness

Significant changes in crispness or hardness or softening of the flesh of the fruit do occur as part of the ripening process. As the peel of the fruit turns from green to yellow, it is corresponded by important textural transformations in the pulp (Smith *et al.*, 1990). At optimal ripening stage, the pulp becomes tenderly soft and as it moves into the overripe stage, the pulp then becomes extremely soft or mushy (Dadzie and Orchard, 1997). This textural loss has been linked to certain processes such as cell wall breakdown due to pectic substances solubilization and also starch breakdown to form sugars (Ali and Abu-Goukh, 2005; Anthon *et al.*, 2011).

In fruits like banana, plantain, guava, mango, and tomato, fruit softening has been found to positively correlate with increasing enzymatic activities and also follows the climacteric pattern of their respiration. These textural changes in fruits turn to greatly affect the quality, shelf life and how fruits are handled after harvest (Ajayi and Mbah, 2007). Measurement or determination of fruit firmness is normally achieved by either using a texture analyzer or by the use of human instruments through sensory analysis (Dadzie and Orchard, 1997).

2.10.3 Changes in total soluble solids (TSS)

This quality basically gives the amount of increase soluble mineral content in fruit as it ripens. This increase in total soluble solids as the fruit ripens is as a result of the conversion of polysaccharides to simple sugars (Kader, 1992). This parameter gives a rough index of the level of sugar which is also a determinant of quality and may differ between different cultivars.

As fruits ripen, the total solids remain constant whiles the soluble solids increase. Sugar alone has been found to constitute about 85% of the amount of these soluble minerals in the fruits (Dadzie and Orchard, 1997). Unripe plantains and bananas are high in starch and low amounts of sugar but as they ripen, the starch is converted to sugar up to the point where bananas can have as much as about 25% total sugar (Ayanwale *et al.*, 2016). TSS is an important quality for consumer preference and it is measured by the use of a refractometer. The refractometer gives readings which express the brix level or sugar content by weight and at the indicated temperature (Anthon *et al.*, 2011; Dadzie and Orchard, 1997).

2.10.4 Changes in total titratable acidity and pH

Both the total titratable acidity (TA) and the pH of the pulp are attributes of importance in assessing the quality of ripening (Anthon *et al.*, 2011). The TA is usually a measure of the collective acids including all the volatile and fixed acids or all acids present while the pH gives the acidity or the alkalinity (Dadzie and Orchard, 1997). Since taste is determined by the regulation of acid and sugar levels in the fruit and sometimes fruit maturity, the estimation of these could give a better idea of consumption quality (Anthon *et al.*, 2011).

Generally, fruits at the immature and the matured green stage have high pulp pH and low Titratable Acidity but as ripening progresses, there is a sharp decline in the pulp pH while acidity increases greatly. These indices could therefore be used to predict the rate of ripening and evaluation of fruit taste (Silva *et al.*, 2009). The pH is determined from the filtrate of the pulp using a pH meter or pH electrode and the total titratable acid (TA) is also determined through titration of the pulp filtrate against a standard base, usually 0.1N sodium hydroxide using phenolphthalein indicator (Dadzie & Orchard, 1997). The result is then expressed in terms of the acid that is predominant in the particular fruit. For example, the predominant acid in plantain is malic acid (Josylin, 1970 as in Dadzie & Orchard, 1997).

2.10.5 Changes in starch content

Starch hydrolysis into simple sugars like glucose, sucrose and fructose is the major chemical change that occur during the ripening of plantain (Islam *et al.*, 2013). This conversion leads to sweetening of the fruit due the sugar accumulation and breakdown of starch. It also gives an indication or the degree of fruit ripeness. For example, starch breakdown in plantain is much slower and drags even into the overripe stage as compared to banana where total starch breakdown is usually accomplished at full ripeness stage (Dadzie and Orchard, 1997; Ayanwale *et al.*, 2016). The ripening process can decline the starch content of about 30% and above in plantain to about less than 2% (NARI, 2003).

The starch iodine test is by far the easiest, fastest and the inexpensive method in estimating starch content during ripening (Dadzie and Orchard, 1997). Other researchers have also described other methods like acid hydrolysis and titration methods but these ones are usually time consuming and complex and therefore they require highly skilled personnel to carry it out (Norgia *et al.*, 2008).

2.11 Mechanisms to Delay Ripening and Extend Shelf life

Storing harvested plant parts and keeping them fresh for an extended period of time than they will naturally do is a critical role in the management of fresh fruits and vegetables (El-ramady *et al.*, 2015). It allows for the attainment of greatest value and utility if their supply is extended over and beyond their harvested season (Sousa-Gallagher and Mahajan, 2011). The aim and the design of every storage method or equipment has therefore been to manipulate the primary factors that have the capacity to influence undesirable processes in the stored product and extend the storage life to the possible maximum.

Factors that can affect the quality and shelf life of fresh produce have been grouped into two main groups as primary and secondary factors (Kader *et al.*, 1989; El-ramady *et al.*, 2015). Some of the primary factors mentioned by these researchers are; harvesting at the right maturity stage, proper sanitation procedure, minimizing mechanical injuries, providing optimum relative humidity and temperature, and also some of the secondary factors as; modification of the CO_2, O_2, and/or ethylene gases concentrations. Strategies to manipulate these factors in order to delay ripening and prolong storage life of fresh produce has become very important and this has provoked the evolution of different methods over the years, both conventional and unconventional ones (De Long and Prange, 2003).

2.11.1 Field or natural storage method

This practice is the simplest and the most basic system of storage which is still practiced among some small scale farmers (El-ramady *et al.*, 2015). In this method, crops such as yam, cassava, carrots, potatoes and other tuber are left in the soil or unharvest even when they have reached maturity until such a time that there is a ready market for them. In a similar fashion, fruits like citrus, plantain and bananas are left on the parent plant until preparations for the market are complete (El-ramady *et al.*, 2015). This way, they are kept fresh for a certain period of time even though not for a longer period and their quality may be affected negatively by this method.

In some instances, the crops are harvested and heaped in bulk on the ground or assembled at a common location which may be under a shade or no shade at all whiles waiting to be transported or marketed (Tchango *et al.*, 1999; NARI, 2003). Some may also be kept in bags, bins, baskets, boxes and on pallets but this method relies only on natural ventilation or airflow to remove the heat and the moisture generated in the produce by their respiratory activities. This method is the main form of storage for most market women and handlers of fresh produce in areas where there are inadequate or no proper storage facilities (Ajayi and Mbah, 2003; Ayanwale *et al.*, 2016). Higher levels of losses are usually recorded under this mode of storage and fruit ripening is also quite rampant, especially in the middle of the heaps.

2.11.2 Cold storage

One important factor that affects the quality of fresh produce after harvest is temperature management. The shelf life of fresh produce has been shown to prolong through rapid removal of the field heat immediately after harvest. (Jobling, 2001). Low temperature storage for fresh produce is one of the dominating and the most fundamental technologies after harvest. When the temperature in the surrounding atmosphere and inside the product is lowered, it slows down respiration rate and reduces the resultant ethylene production as well as reducing tissues response to ethylene (Sirivatanapa, 2006). Respiration rate doubles or may even treble for every 10˚C rise in temperature, which also suggest that shelf life is reduced for every 10˚C rise in temperature of fresh produce (Jobling, 2001).

Each fresh produce has its own acceptable range of temperature that it can tolerate, therefore storing a given fruit or vegetable above a certain critical temperature is likely to cause chilling or freezing injuries (Sousa-Gallagher and Mahajan, 2011). Geographical origin of the produce, often times determine their ideal storage temperatures. Most tropical produce does not tolerate storage temperatures below 12˚C whereas those cultivated in the temperate climates can tolerate lower storage temperatures to as low as 0˚C (Jobling, 2001). For example, according Jobling (2001), at 21˚C, some apple cultivars ripen within a day while at -1˚C it ripens in 10 days. In the NARI Technical Bulletin (2003), it is reported that, at an optimal temperature of between 12˚C and 14˚C, the transportation and storage temperature of matured green tropical plantains and bananas could be maximized and the shelf life also extended to between 4 and 5 weeks without any chilling injury.

2.11.3 Modified Atmosphere Package (MAP) and Controlled Atmosphere Package (CAP)

Modified atmosphere package (MAP) operates on the principle of establishing and equilibrium in the gas composition inside the package through the interplay between the respiration rate of the product and the permeability of the package. It employs either micro-perforated or unperforated films that have selective permeability for CO_2 and O_2 gases (Kupferman and Sanderson, 2001). Controlled Atmosphere (CA) on the other hand, precisely monitor and control the concentration of gaseous atmosphere around the fresh produce by altering Oxygen and the carbon dioxide concentrations during the storage period (Hoen *et al.*, 2009; Sousa-Gallagher and Mahajan, 2011). They both have been found to be very effective in prolonging the shelf life of many fresh produce (Kader *et al.*, 1989; Kupferman and Sanderson, 2001). There are reports by several researchers indicating the use of MAP and CAP as tool to prolong the postharvest life of several perishables like apples, cabbages, pears, cherries, raspberries, blueberries, bananas and plantains, and also some minimally processed vegetables like lettuce, broccoli, cabbage and celery (Cameron *et al.*, 1995; Kupferman and Sanderson, 2001; Kader *et al.*, 2005; Yahia, 2006)

2.11.4 Use of ethylene absorbents/scrubbers

The ability to control the ethylene produced during fruit storage is very key in preventing unwanted discoloration and prolonging the postharvest life of fruits (Bhattacharjee and Dhua, 2017). Use of ethylene absorbents to either reduce or completely get rid of the ethylene produced during storage has become a common technology in most commercial fruit handling (Park *et al.*, 2016). The mode of action of the ethylene absorbents is through the use of potassium permanganate (Prasad and Kochhar, 2014). When the $KMnO_4$ is impregnated unto a porous inert mineral and inserted into the storage environment, it oxidizes the ethylene produced by the fruits into water and carbon dioxide and by this, it prolongs the postharvest life of fruits by delaying softening and other adverse effects of ethylene (Hasan and Hasan, 2014).

The use of potassium permanganate to delay ripening in climacteric fruits like apples, bananas, tomatoes, plums and payayas have been reported in literature (Park *et al.* 2016; Bhattacharjee and Dhua, 2017). Sharma *et al.* (2012) were able to extent the shelf life of Japanese plums (*Prunus salicina* Lindell) cv. Santa Rosa from 3-4 days to between 9 and 12 days when it was stored with potassium permanganate at a temperature of 38˚C±2 and RH of 68%±4. The shelf life of mature green plantains being extended to 4 weeks when stored in polyethylene bags with potassium permanganate ($KMnO_4$) wrapped in porous paper at a temperature of 29.4˚C and up to 7 weeks at a temperature of 12.7˚C has also been reported (NARI, 2003).

2.11.5 Use of polyethylene sheets for fruit storage

The deterioration of fruits during storage is reported to be partly due to moisture loss which result mainly from respiration and transpiration processes (Ramin and Khoshbakhat, 2008). These resulted in the use of extensive wax coatings on fruits but that also came with its own difficulty and other technical problems of its usage in terms fruit quality attributes and so not too much have been seen of it (Ramin and Khoshbakhat, 2008).

When fresh produce is packaged in perforated polyethylene bags or plastic film lining, moisture and weight loss have been found to reduce due to the high relative humidity that is inside the package (Elkashif *et al*., 2005). It also has the potential of modifying the gaseous atmosphere around the produce hence providing what has become more or less an alternative to modified atmosphere package for some local fresh produce handlers in developing countries (Ramin and Khoshbakhat, 2008).

Due to their cheap and availability nature they are used in recent times to package diverse food products more than even the conventional use of leaves locally. Extensive used of polyethylene film packaging to reduce water loss and enhance fruit quality seem to date back into years. Hussain, *et al.* (2004) reported micro-perforated polyethylene bags having the capacity to preserve many quality attributes in citrus. In a study conducted on melons, fruits stored in polyethylene bags retained good organoleptic properties than those stored in modified atmosphere (Rodov *et al*., 2002). Sugri and Johnson (2009) also used polyethylene bag together with sawdust to provide a Modified atmosphere storage for different varieties of plantain which yielded some positive results of increasing the shelf life by between 11 and 16 days, and when $KMnO_4$ was added, they recorded and additional 2days. Clearly, there is so much potential in polyethylene bag that could be exploited for the storage of fresh produce. This potential could be further enhanced when combined with other storage forms.

2.12 Synopsis of Literature Review

The review has re-emphasized the importance of plantain to the national economy contributing in the areas of food, job security and a source of rural income. In spite of these benefits derived from plantain, postharvest losses still hover around 35% in developing countries like Ghana which is quite worrisome. These losses have been identified to occur at various stages in the value chain and have also been found to be greatly resulting from a wrongly held view by most of the handlers that, plantain do not go bad due to its many uses locally and the comparatively robust nature of the plantain.

Clearly, the major problems encountered with plantain postharvest are concentrated in the areas of transportation and how to extend the green life. There are also a number of factors, both inherent and external that predispose the plantain to deterioration which when not controlled can be devastating. These have been basically because plantain is a fresh produce and unlike the durables, its handling is quite delicate and complex. The processes of respiration and ethylene production are also of great importance in their handling.

Handlers of plantain, especially, on the local markets are faced with major difficulties of getting proper storage and ripening methods to help them overcome these difficulties. Most of the already available handling methods and strategies have not seen much success in adoption by the local handlers due to cost issues and sometimes also, the sophisticated nature of the interventions. Resultantly, local handlers have in their own way improvised methods that may be unapproved and sometimes harmful to the health of consumers.

Evidently, the gap of coming up with affordable but effective means dealing with some of these postharvest problems especially in packaging, storage and the ripening processes that local handlers could adopt with ease still exists.

3.0 MATERIALS AND METHODS

3.1 Materials:

3.1.1 Sample Source

Matured green 'Apantu pa', a locally known cultivar of the False Horn variety of plantain cultivated at University of Ghana Forest Horticultural Crops Research Centre (FOHREC), Okumaning, Kade in the Eastern region was obtained and used for all experiments in this study. This variety was chosen because of its local predominance and consistent agronomic performance.

All samples of plantain used were at least 90 days after flowering and physiological maturity were examined using the maturity indices prescribed by Dzomeku *et al.* (2016).

Only the second and third hands on the bunches were used for the experiments.

3.1.2 Evaluating the handling practices for plantain on the local markets.

Semi-structured questionnaires were used and the responses captured on a voice recorder.

3.1.3 The effect of different forms of packaging used in transporting plantain on the quality of plantain.

A Wooden box of dimensions; 51x64x25 cm, Paper box of dimensions; 23x38x25 cm and Plastic basket of dimensions; 32x33 cm were used.

The lining materials used were; fresh plantain leaves obtained from the harvested plantain and transparent polyethylene sheet of thickness 0.05 mm.

3.1.4 Evaluating the effects of different colors of polyethylene sheets on the ripening behavior and postharvest shelf life of plantain.

Four different colors of Low Density Polyethylene (LDPE) sheets of thickness 0.05 mm were used.

The colors of the polyethylene bags used; white, yellow, light blue and transparent/colorless.

3.1.5 Evaluating the use of shredded plantain pseudo stem as a preservation material for plantain after harvest.

Granulated potassium permanganate, the pseudo stems of the harvested plantains (dried and shredded), Low Density Polyethylene (LDPE) sheets (transparent) of thickness of 0.05 mm and a Paper box of dimensions; 23x38x25 cm were used. NB: The transparent polyethylene sheet was chosen because in the experiment in objective 3 of this study, it was found to give similar results as the control. Therefore, its interference was expected to be minimal as compared to any other color of poly bag.

Adam equipment Co. Ltd., Milton Keynes, UK, Sn: AE271693591, Max. Wt.: 15kg was used for weighing samples.

3.1.6 Determining the influence of calcium carbide (CaC_2) and corn dough on the ripening behavior on plantain.

Powdered calcium carbide (carbide dust), a 24 hours old corn dough, 2 days old plantain, LDPE polyethylene bag and used rice sacks were used.

3.2 Methods

3.2.1 Evaluating the postharvest handling practices for plantain.

3.2.1.1 Pretest:

Before the actual survey, a pretest was conducted on three fresh produce namely; Okro, Tomato and Plantain, and three main areas which were packaging, transportation and ripening were considered. Market women at Abgobgloshie, Madina, Dome and Texpo (Spintex) Markets (all in Accra) and also Adeiso market in the Eastern region were interviewed. At each market, three (3) traders of each fresh produce were interviewed bringing the total number of interviewed traders to 15 for each fresh produce and 45 in all.

For okro, all 15 representing 100% of the okro traders interviewed said they packaged their produce both during transit and on the market, 33.3% agreed to have some difficulties with transportation and 66.7% had no problems with transportation. The third area of consideration which was ripening was not applicable in the case of Okro.

For tomato, 100% of the people interviewed said they packaged their produce, 60% had transportation difficulties while 40% did not and 100% of the respondents said there was no need to hasten ripening, 93.3% had no proper means of delaying ripening while 6.7% said they could delay ripening by natural ventilation.

On plantain, only 13.3% did give some form of packaging to their produce while 86.7% did not package, 80% of the respondents said it was difficult getting their produce to the market center while 20% disagreed there were problems with transport, 100% had no proper means of delaying ripening apart from natural processes and 73.3% said they had indigenous ways of hastening ripening while 26.7% did not.

Plantain was therefore chosen out of the three produce due to the many challenges they had than the others based on the areas that were considered.

3.2.1.2 Main Survey

Semi structured questionnaires were administered to fifty (50) market women and handlers of plantain at; Abgobgloshie, Madina, Dome and Texpo (Spintex) Markets (all in Accra) and Adeiso market in the Eastern region between September and November 2016. Selection of these markets and respondents at the markets were by convenience.

Questions were read and explained to respondents in their own dialects and a voice recorder was used to capture their responses to the various questions asked which was later transcribed verbatim.

The responses were then scrutinized and after the common problems of the traders were identified, the other four specific objectives of this study were outlined from those problems identified.

3.2.2 The effect of different forms of packaging used in transporting plantain on the quality of plantain.

3.2.2.1 Experimental Design

Four different packaging materials, namely: wooden box, plastic basket and paper carton were experimented to see their impact on the quality of plantain after transport. A 3x3 full factorial design with three replications was used. The experimental factors were packaging material (wooden box, plastic basket and paper carton) and the lining material (plantain leaves, perforated transparent polyethylene film and no lining).

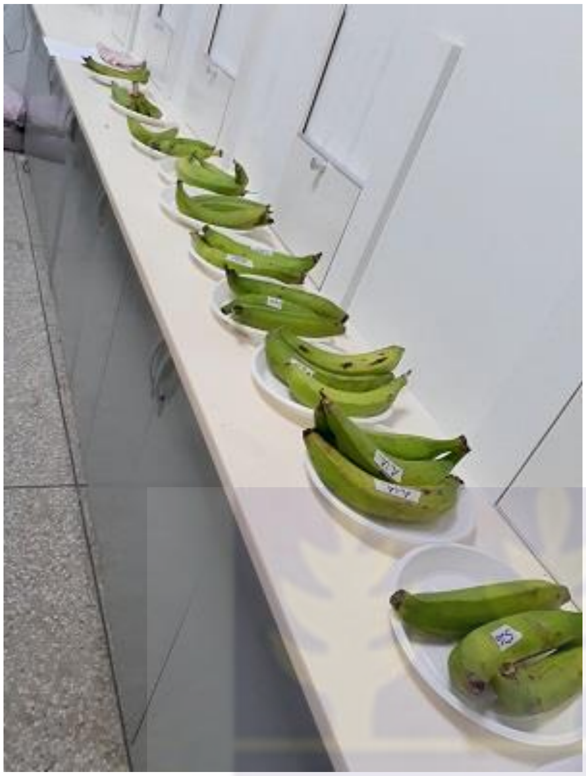
3.2.2.2 Procedure

Harvesting of the plantains was done around mid-morning (10-11am), they were de-handed and removed into single fingers using a kitchen knife. They were then mixed and picked in singles and arranged in the various packaging materials on the farm immediately after harvest. They were thereafter transported from the Research Center at Kade to the Food Science and Nutrition Laboratory at the Department of Biochemistry, University of Ghana main campus (About 2hours 30minutes journey).

Plate 3.1 Plantain in wooden (left) and paper (right) boxes with different lining materials

Plate 3.2 Plantain in a plastic basket with a perforated polyethylene lining.

On arrival, samples were kept in their respective package till the next morning (5pm-10am) when the parameters were measured using sensory evaluation. Five random samples were selected from each replication and put together as a unit for the sensory evaluation. The overall scores given by each of the five trained judges were used as a representative of each replication. The parameters measured were; Level of bruising, Peel/pulp firmness and Color of peel



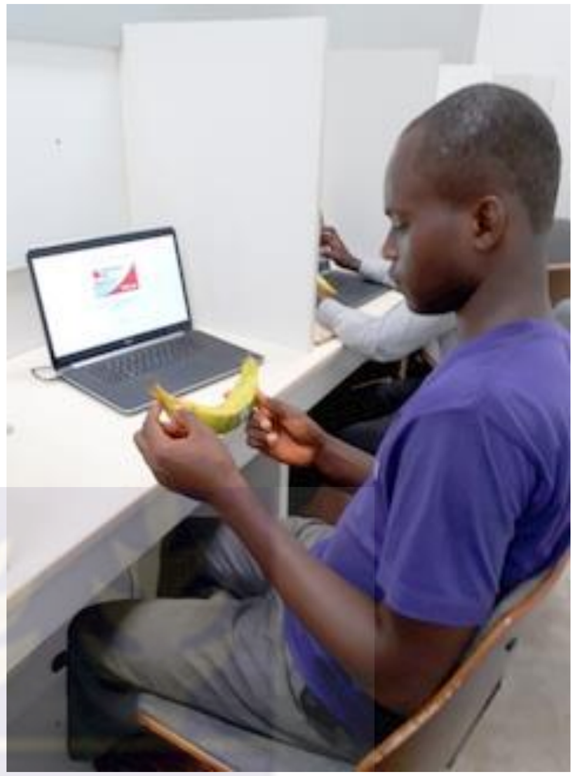


Plate 3.3 Coded samples of plantain for sensory evaluation (left) and a panel member evaluating a plantain sample (right).

3.2.2.3 Training of Quality Grading Panel

Before the actual sensory evaluations, four consecutive training sessions were organized for the five-member grading panel at the Sensory Laboratory, Department of Nutrition and Food Science- University of Ghana, in order to come up with a common scale that was used to measure all the three parameters. This trained panel was used for all the sensory evaluations in this study which was limited to physical qualities measurements, namely; degree of bruising, firmness and color.

3.2.2.3.1 Firmness

To calibrate a scale for measuring firmness, different food items which had various degrees of hardness were presented to the panel to assess and group them according to their intensity of hardness. This assessment was on a scale of 0-5. The firmest/hardest (as hard as stone/wood) received a score of 0 and the softest (as soft as cheese) a score of 5. Every panel member was allowed to touch and press gently each of the items presented and gave a score based on the scale. Among the different food items presented to the panel were; nutmeg, an apple, unripe pawpaw fruit, boiled and peeled egg, overripe mango fruit with brown flecks, fully ripe tomato fruit, carrot, ripe avocado, cheese, pan cake and 500ml sachet water.

Afterwards, the panel discussed and came to a consensus on the actual score for each of the items presented and then grouped them to serve as a rule for doing the actual evaluation. In the end, the intensity scale agreed on and used for the measurement of pulp firmness is as shown in Table 3.1.

Table 3.1 Quality grading scale for firmness

Quality Parameter	Description	Score
Firmness	Very firm	1
	Firm	2
	Soft	3
	Very soft	4
	Extremely soft (with water oozing out)	5

3.2.2.3.2 Color

For color grading, the unripe (all green color) and overripe (dark brown color with a trace of yellow) plantain fingers were used as the end points to calibrate the quality scale for ripeness. Plantains at different stages of ripeness were also presented to the panel for them to score according to peel color. Level of ripening was scored based on the intensity and the degree of the spread of the green color. In the end, a scale of 1 to 9 was agreed upon to be used for grading color. Table 3.2 shows the scale used for the grading.

The Color chart for grading the ripeness of banana (adapted from Geest, UK) was also used to aid the process.

Table 3.2 Quality grading scale for color

Quality Parameter	Description	Score
Color	All green	1
	Green with a trace of yellow	2
	More green than yellow	3
	More yellow than green	4
	Yellow with a trace of green	5
	All yellow	6
	All yellow with brown speckles	7
	More spread of brown in the Yellow	8
	Dark brown with a trace of yellow	9

3.2.2.3.3 Bruises

On bruises, the panel was shown the difference between a defective (poor quality) and a non-defective (high quality) plantain by presenting to them a highly bruised plantain fingers and one without any bruise/damage. For the purposes of grading, any kind of mechanical damage on the plantain fingers such as scratches, breakages, abrasions, skin darkening and any kind of damage was scored as a bruise. The panel was also shown the differences between mechanical damages and physiological damages, as well as mechanical damages that occurred before harvest. It was also agreed that, both physiological damages such as peel splitting, sun scald, varietal variation in the intensity of the green color and mechanical damages that did not occur during the postharvest period such as damage by birds, rodents and other animals on the field, (if they were found on the plantain) did not qualify as a postharvest damage (bruise). Quality grading in terms of bruising was scored on a scale of 1-5, judging from the percentage damage on the total surface area of the fruit. Table 3.3 shows the final scale used for grading bruises.

Table 3.3: Quality grading scale for bruises

Quality Parameter	Description	Score
Bruises	Low (up to 5%)	1
	Moderate (5-10%)	2
	High (10-15%)	3
	Very High (20-30%)	4
	Extremely High (Above 30%)	5

3.2.3 Evaluating the effects of different colors of polyethylene sheets on the ripening behavior and postharvest shelf life of plantain.

3.2.3.1 Experimental Design

Four different colors of polyethylene sheets (white, yellow, light blue and transparent/colorless) of same thickness (0.05mm) were used. A completely randomized design with five treatments (the different polyethylene bag colors and the control) and three replications for each was used.

3.2.3.2 Procedure

Five fingers of plantain were randomly selected and packaged in each polyethylene sheet and the opened end of the polyethylene bags were closed by wrapping a masking tape around them as shown in Plate 3.4. They were kept on the shelves at the laboratory, sufficiently spaced out from each other and stored at room temperature till ripening occurred in all treatments. Temperature within the poly bags were measured before random samples were taken on each day of analyses.

Data were collected after every 48 hours (two days' interval) and the parameters measured were; **Pulp Firmness, Peel Color, Total Sugars/Starch Content, Reducing Sugars, Titratable Acidity (TA) and Total Soluble Solids (TSS)**.

3.2.3.3 Analyses

Total Sugars/Starch Content and Reducing Sugars were determined using the Lane and Eynon method described by James (1995).

Total Titratable Acidity (TA) was determined using the titration method described by Dadzie and Orchard, 1997 in the INIBAP Technical Guidelines 2.

Total soluble solids (TSS) was determined using the Abbe's handheld refractometer.

Peel Color and Pulp Firmness were measured using sensory evaluation.

The mercury filled clinical thermometer (Fisher brand, UK) was used to measure the temperature readings in the bags.

Plate 3.4 Plantain fingers packaged in polyethylene bags of different colors.

3.2.4 Evaluating the use of shredded plantain pseudo-stem as a preservation material for plantain after harvest.

3.2.4.1 Experimental Design

A completely randomized design with four treatments and three replications was used. The treatments were; shredded pseudo stem only, $KMnO_4$ only, shredded pseudo stem and $KMnO_4$ and the control.

NB: The use of $KMnO_4$ as a treatment was to compare its results with the shredded plantain pseudostem since it is a known ethylene absorbent with the ability to delay ripening in fruits (Sharma *et al.*, 2012; Park *et al.*, 2016; Bhattacharjee and Dhua, 2017)

3.2.4.2 Procedure:

3.2.4.2.1 Shredded plantain pseudo stem

To obtain the shredded pseudo stem, the stems from the harvested plantains were cut and chopped into smaller sizes to enable early drying. It was then dried on a wooden tray in the sun at a temperature of about 32˚C for 4 days (or till when it has lost almost all the moisture in it). It was then shredded using the hand and scissors into much smaller sizes (like the form of sawdust). Pipe borne water with a pH of 7 was sprinkled on it to raise the moisture content again to 73.5%. 1.5 kg was weighed and used for each treatment.

3.2.4.2.2 Potassium permanganate ($KMnO_4$)

The $KMnO_4$ used was in granular form and a quantity of 21.30 g which represented 1% of the average total weight of the samples (the average weight of all seven fingers of plantain about was 2129.4g) was used. The $KMnO_4$ was then packaged in a polyethylene sheet of 0.05 mm thickness and holes were punched around it using a piece of broom before use.

3.2.4.2.3 Experimentation

Each treatment comprised of seven (7) randomly selected plantain fingers. The fingers were completely covered with the shredded stem which was spread on a transparent polyethylene sheets. Care was taken to ensure that the fingers of plantain were totally covered by the shredded pseudo stem. The packaged $KMnO_4$ was inserted into the shredded pseudo stem where necessary. They were altogether carefully wrapped with the transparent polyethylene sheet and the edges sealed with a masking tape to prevent escape of gases. They were then put into a paper box (as shown it Plate 3.5) and kept on the shelves at the Laboratory throughout the experimental period.

Data were collected on a 4 days' (96hrs) interval until ripening occurred in all treatments. On each day of analyses, temperature readings in the bags were measured first, after which one random sample from each treatment was randomly selected and used for the analysis.

The parameters measured were the same as in specific objective 3.

Plate 3.5 Packaging procedure: Fingers of plantain together with $KMnO_4$ and Shredded plantain pseudo stem spread on a polyethylene sheet (left) and plantain covered with shredded pseudo stem, sealed in a polyethylene bags and stored in paper box (right).

3.2.5 Determining the effect of calcium carbide (CaC_2) and corn dough on the ripening behavior on plantain.

The primary objective of this experiment was to verify the role of corn dough in the ripening of plantain as claimed by some market women at Agbogbloshie market in Accra. Specifications were therefore made according to how it is practiced by the market women.

3.2.5.1 Experimental Design

A completely randomized design with four treatments and three replications was used. The treatments were; Corn dough only, Calcium carbide only, Corn dough and Carbide (Both) and none as the control.

3.2.5.2 Procedure

For each unit of experiment, 1kg of 24hours old corn dough (prepared by soaking dried maize grains in water for 3 days, milling with a corn mill, mixing it water to form a dough and covering and leaving it for 24hours) was packaged in a transparent polyethylene bag. A piece of broom was used to punch holes in the polyethylene bag containing the corn dough. 0.5kg of powdered calcium carbide was also poured into a polyethylene bag and used each replication (where required). Each treatment comprised of ten (10) fingers of plantain.

The plantains were packed into the sack with the calcium carbide placed in the middle of the heap with one end of the polyethylene bag opened (to allow for the release of the gas) and the corn dough also placed by the side of the calcium carbide (as shown in Plate 3.6). The opened ends of the sacks containing both the treatments and fingers were tightly tied with a rope and brought outside of the laboratory and left in the open for 24 hours. The sacks were taken inside the laboratory on the next day (24 hours later) and the temperature within the sacks were taken on three consecutive times at a 5 minutes' interval by inserting the thermometer into the sacks while still tied. The sacks were finally opened and the fingers were removed for analyses.

NB: The plantains used in this experiment were 2 days old after harvesting and this is because from the survey, the plantain the market women used spent averagely 2-3 days in transit before getting to the market.

Data were collected after the samples have been removed and left on the shelves for 5 hours.

The parameters measured were the same as in specific objective 3 and 4.

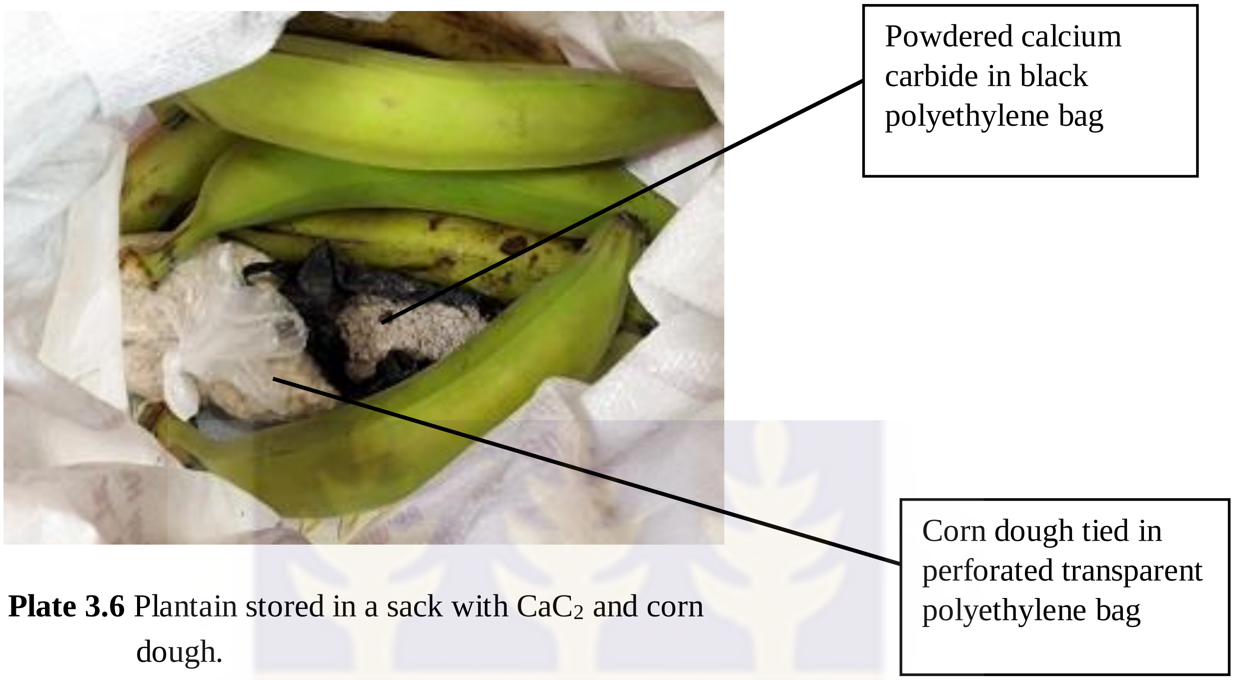


Plate 3.6 Plantain stored in a sack with CaC_2 and corn dough.

3.3 Data Analyses

Data entry was done using Microsoft excel 2016 version and statistical analyses were done using the Minitab software, version 17.

ANOVA was used to determine the statistical differences between treatments in the experiments conducted in specific objective 2 to 5 at $P \leq 0.05$.

Data has been presented in charts, graphs and tables.

4.0 RESULTS AND DISCUSSION

4.1 Survey on postharvest handling practices for plantain on the local markets.

A total of fifty (50) plantain handlers (both traders and distributors) were interviewed at Agbogbloshie, Madina, Dome, Texpo (Spintex) markets, all in Accra and Adeiso market in the Eastern region. The results from the survey showed that; out of the 50 plantain handlers interviewed on what they believed to be the major postharvest problem associated with plantain, 12 representing 24% said distribution/transportation, 10 representing 20% said it was how to delay ripening, 9 representing 18% said inadequate storage facilities, 8 representing 16% said packaging, hastening ripening had 7 which amounts to 14% of the total number interviewed, 4 representing 8% chose financial difficulties while nobody chose processing (0%). Only one (1) person representing 2% stated the problem as the unsanitary environment on the market where they sell their produce. The results have been presented in Figure 4.1.

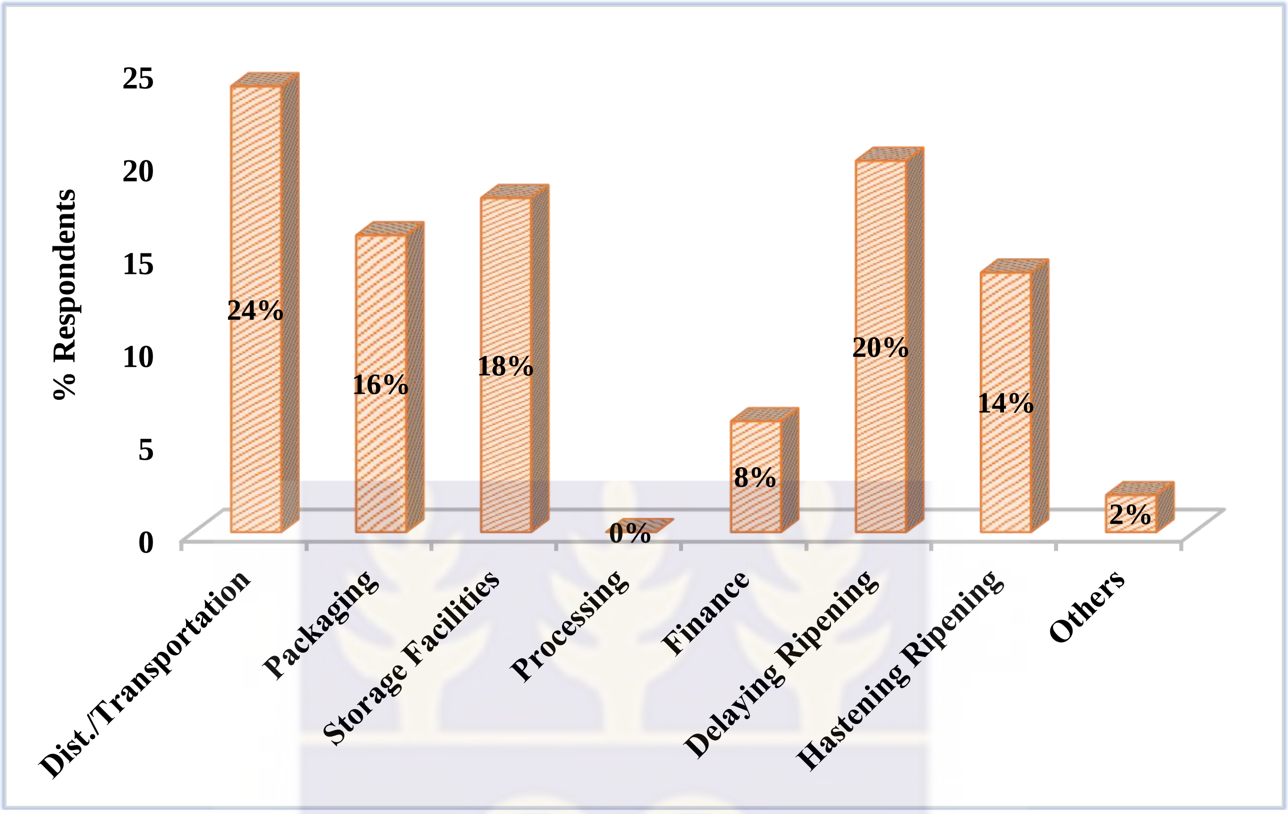


Figure 4.1 Percentage of respondents interviewed at five markets citing various postharvest problems of plantain.

From the survey results, it was deduced that the major problems that handlers of plantain on the visited Ghanaian local markets generally face are; inefficient distribution and transportation systems, difficulty in delaying ripening, inadequate storage systems improper ripening techniques and poor packaging. This outcome mirrors the findings of Ajayi and Mbah (2003) as stated in Ayanwale *et al.* (2016).

Adu-Amankwa *et al*. (2011) also reported transportation, specifically, the bad nature of the roads network as one of the major problems of market women in Ghana. According to them, the bad road network made women to spend an average of 2-3 days transporting plantain from the growing area. They further added that, high postharvest losses recorded in plantain through fruits softening, rotting and early ripening are as a result of poor storage facilities and poor storage conditions. This also implies that, none of the problems listed above is a standalone since one can easily implicate the other. For example, bad road networks could delay transportation and this will affect the efficiency of the distribution system which might also lead to produce ripening before they get to the market. This could also increase the level of deterioration and raise the overhead cost of transportation thereby reducing profit. There is therefore the need for these outlined problems to be viewed together as a unit and tackled at the vital points right after harvest so as to curtail the chances of occurrence of other problems downstream the handling chain.

On their part, Dzomeku *et al.* (2011) stressed the inefficient distribution system and affirmed that, plantain marketing in Ghana is bedeviled with a scattered large number of producers who are extremely far from a large number of consumers but only connected by a few distributors and wholesalers. Ekunwe and Ajayi (2010) in a similar vein listed transportation and storage as some of the major constraints encountered by farmers in plantain production.

The findings of this survey has therefore revealed that, although there have been some efforts by researchers and governments to increase average national production of plantain in Ghana and the sub region over the past two decades (SRID-MOFA, 2014; FAOSTAT, 2014), a lot more remains to be done to ensure that what is produced actually gets to intended consumer or usage and not lost along the value chain.

It also came to light from the survey that, there is the need for a conscious effort to debunk the general impression held by a section of the society that, 'plantain can be consumed at any stage of ripeness and so no special postharvest treatments are required', a notion that militates against any technological improvement on plantain postharvest handling practices, as also reported by Cropley and Morris (1993) as in Adu-Amankwa *et al.* (2011). From the survey conducted, it was obvious that the traders still held this belief but they also attested to the fact that as the plantain goes through the various stages of ripening, the price keep changing with the full green plantain fetching premium prices always. To most of the handlers encountered on the markets, they believed they do not lose because overripe plantains were not disposed of as is the case for tomato and some other fruits. Clearly, what these handlers failed to also realize was, even though they could still get some market for the overripe plantain, it was at a reduced price than compared with the green plantain. This reduction in price affects their overall profit and so they fail to attain the full benefit of what they could have originally gained from their produce. This also makes some of the traders to unduly hike the prices of their produce leading to the high prices of plantain sometimes encountered on the markets. Efforts should therefore be geared towards educating plantain handlers on this wrongly held belief so that postharvest innovations on plantain can be smoothly implemented without difficulties.

Some steps to help reduce mechanical damages during transportation, extend the green life and problems with the ripening have been experimented upon and discussed under subsequent headings in this paper.

4.2 The impact of different forms of packaging used in transporting plantain on the quality of plantain.

The capacities of wooden box, plastic basket and paper carton as packaging materials as well as plantain leaves and polyethylene materials used as lining materials to reduce bruising and other forms of mechanical injuries inflicted on the plantain during transit were studied. The results from the different packaging and lining materials in terms of bruises and firmness showed significant differences between the packages at $P \leq 0.05$. For bruises, there were significant differences between the various forms of packaging with the control being the highly bruised. In terms of pulp firmness, there was a significant difference between the control and all the other forms of packaging but no significant difference between the various packaging materials. There was however, no significant difference between the different forms of packaging for peel color. The results are presented in Table 4.2.

Table 4.2 Effects of different forms for packaging and lining on bruises, peel color and firmness assessed through sensory evaluation.

Form of Package	Bruises	Peel Color	Firmness
Wooden box with leaves lining	1.33 ± 0.58^{bc}	1.33 ± 0.58^{a}	1.00 ± 0.00^{b}
Wooden box with polyethylene lining	1.00 ± 0.00^{c}	1.33 ± 0.58^{a}	1.00 ± 0.00^{b}
Wooden box with no lining	2.00 ± 0.00^{b}	1.00 ± 0.00^{a}	1.00 ± 0.00^{b}
Plastic basket with leaves lining	1.00 ± 0.00^{c}	1.67 ± 0.58^{a}	1.33 ± 0.58^{b}
Plastic basket with polyethylene lining	1.00 ± 0.00^{c}	2.33 ± 0.58^{a}	1.00 ± 0.00^{b}
Plastic basket with no lining	1.33 ± 0.58^{bc}	1.67 ± 0.58^{a}	1.00 ± 0.00^{b}
Paper carton with leaves lining	1.33 ± 0.58^{bc}	1.67 ± 0.58^{a}	1.00 ± 0.00^{b}
Paper carton with polyethylene lining	1.00 ± 0.00^{c}	2.00 ± 0.00^{a}	1.00 ± 0.00^{b}
Paper carton with no lining	1.00 ± 0.00^{c}	1.67 ± 0.58^{a}	1.00 ± 0.00^{b}
Control	4.00 ± 0.00^{a}	1.00 ± 0.00^{a}	2.00 ± 0.00^{a}

- Data are presented as means±SD. Means within a column with different superscript are significantly different at $P \leq 0.05$. (See Table 3.1, 3.2 and 3.3 for grading scales for parameters).

The results from Table 4.2 shows that, all the different forms of packaging scored better than the control which was without any form of packaging in all the parameters considered with the exception of peel color. It therefore means that, introducing some form of packaging for plantain during transportation could help reduce the level of mechanical damages that are inflicted on the plantains during transit.

Also, plantain transported using different forms of packaging used in this experiment will arrive with a much firmer pulp/peel than just stacking them in the vehicle without packaging. The difference in bruises and firmness of the peel and the pulp of the plantain transported without packaging and the ones with packaging obviously resulted from the difference in the degree of vibration, compression and knocking of the plantains against each other as well as knocking against the walls of the vehicle as the vehicle made undulating movements on the bad road during transportation. In this experiment, it is clear that the impact of these sources of damage to either cause external or internal damages seemed greatly reduced by the introduction of the packaging, hence the firmer and less bruised plantain recorded in the packaged ones.

The National Agricultural Institute (NARI), the New Guyana Marketing Corporation and the Ministry of Fisheries, Crops and Livestock of Guyana in their Joint Technical Bulleting (2013) on plantain postharvest care and market preparation reported that, considerable peel damages are usually incurred on the plantain fingers in the transportation process and further proposed that future measures that could curb this menace might include the use of foam lining on the walls and the underside of vehicles/trucks as well as between bunches during transit. Also, other research works have proven that the major cause of spoilage and early ripening are as a result of the harsh conditions plantains have to endure and the damages incurred during the postharvest activities such as during transportation and storage (Adeniji *et al*., 2010). These reports emphasize the fact that the introduction of packaging during plantain transportation has the capacity to contribute enormously in reducing the level of postharvest losses in plantain.

Ayanwale *et al.* (2016) in similar fashion also suggested that an innovation that could help reduce the transportation losses and damages to the barest minimum and preserve the freshness in quality of plantain would be to transport them in some specialized wooden airy trays. They were however quick to add that, because plantain handlers normally would not want to incur any extra cost on transportation, using cheap materials to make these packaging materials or a support from government, plantain producers' associations and NGO's might go a long way to help in the adoption of packaging for plantain. Fortunately for these handlers who might not want to incur extra transportation cost, the materials used in this experiment are ones that are locally available and affordable therefore, it becomes 'an easy to adopt' innovation without handlers having to complain about cost or availability of materials. These are also packaging forms that handlers can easily improvise on their own without any requisite high technical know-how.

Finally, there is also a report that says that the leaves of the plantain after harvest are virtually used for nothing except in some cases where they are used as to feed livestock (Abiodun and Falade, 2010) or being left to decompose into the soil as organic manure or sometimes burnt when they dry. With the outcome from this experiment, farmers and handlers could now put the leaves of their harvested plantain into an extra beneficial use by using them as liners for their packaging material than just leaving them to rot or waste.

4.3 Evaluating the effects of different colors of polyethylene sheets on the ripening behavior and postharvest shelf life of plantain.

Plantain was wrapped in polyethylene bags of differing colours over a period of time until fully ripe. From the results obtained for the measured parameters (starch content, reducing sugars, total soluble solids, peel color, pulp firmness and Titratable acidity) ripening was generally slow in the black polyethylene bag and faster in the blue polyethylene bag. The analysis of the results also showed there was significant difference in the parameters at the different time intervals at $P \leq 0.05$. The trend was not so clear as at the 48th hour mark but from the 96th hour, a clear trend of the black polyethylene bag recording higher values in percentage starch content and lower reducing sugar content till the end of the experiment (an indication of slow ripening rate) while the light blue polyethylene bag from the 144th hours onward, recorded lower starch content and higher reducing sugars till the end of the experiment (an indication of faster ripening rate) as shown in Figs. 4.3.1 and 4.3.2 was observed.

Also in Figs. 4.3.1 and 4.3.2, using the starch content and the reducing sugars as indicators of ripeness, ripening seem to have taken place at faster rate for samples in the white polyethylene bag for the first four days (up to the 96th hour) than for all the other colors of polyethylene bag, including even the light blue polyethylene bag in which ripening was ultimately faster.

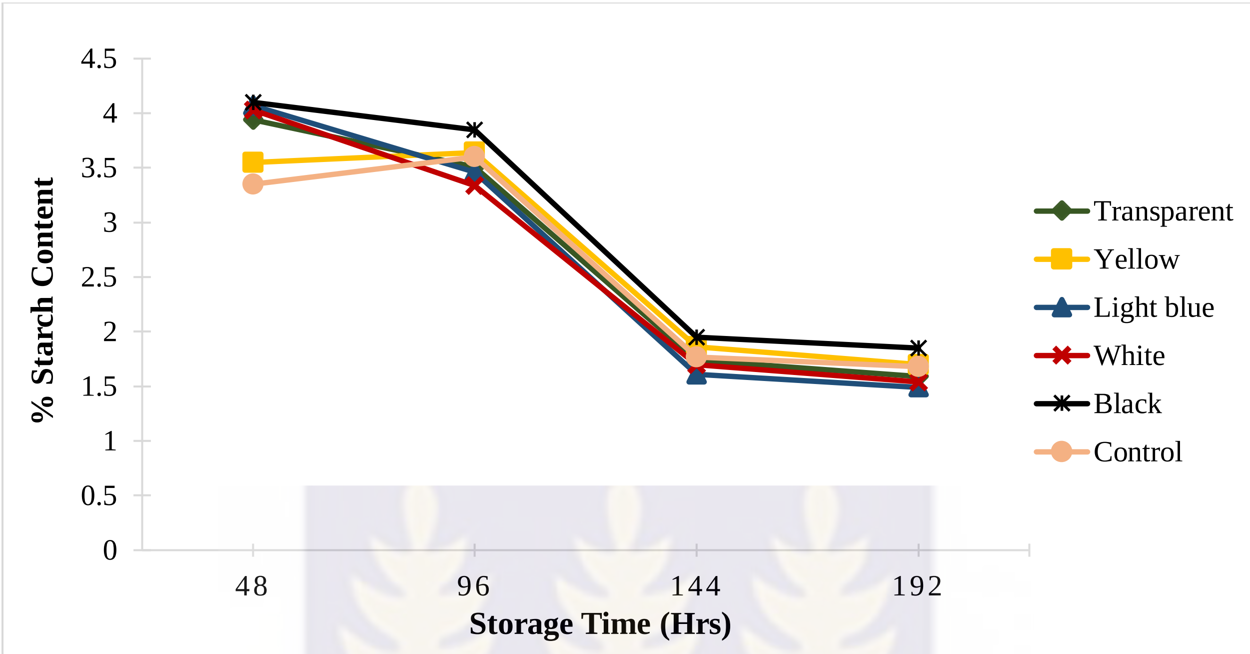


Figure 4.3.1 Changes in Starch content of plantains stored in different colors of polyethylene bags for up to 192 hours.

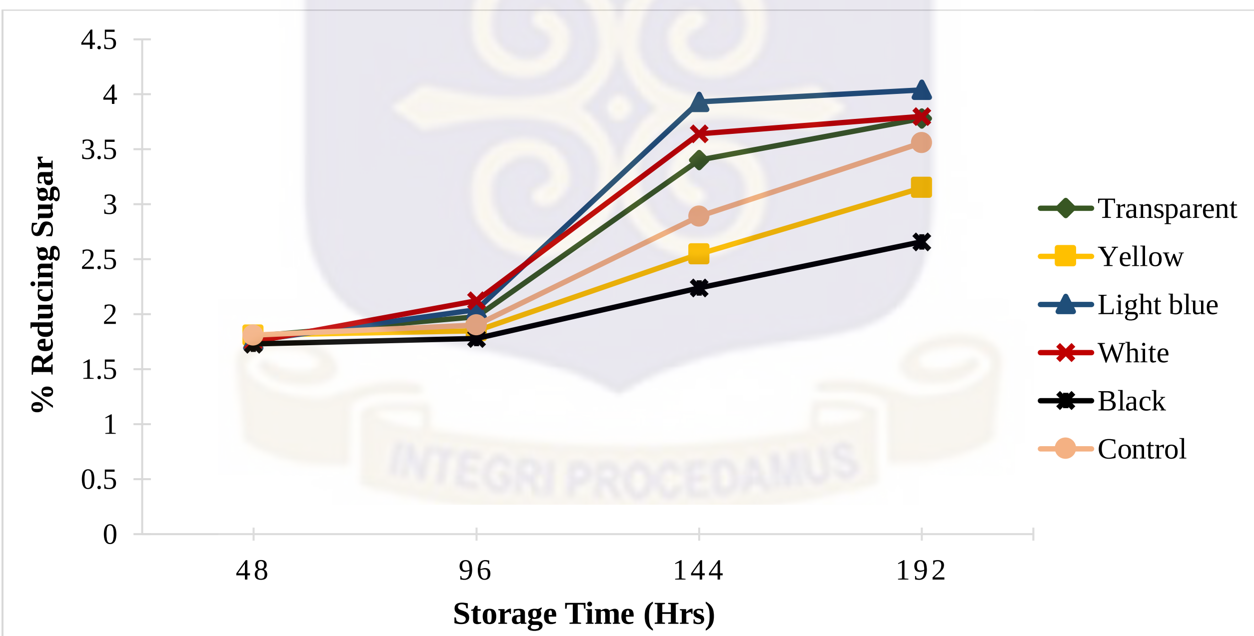


Figure 4.3.2 Changes in Reducing Sugar content of plantains stored in different colors of polyethylene bags for up to 192 hours.

Also, Figures 4.3.3, 4.3.4 and 4.3.5 show a similar trend of all the plantains stored in the different colors of polyethylene gradually increasing in total soluble solids, changes in peel color and pulp firmness as the plantain fingers moved from unripe to ripe stage. Generally, plantains in the black polyethylene bag increased at a much slower rate in all the parameters than for all the other colors of polyethylene bags while those in the light blue polyethylene bag increased on a much faster rate.

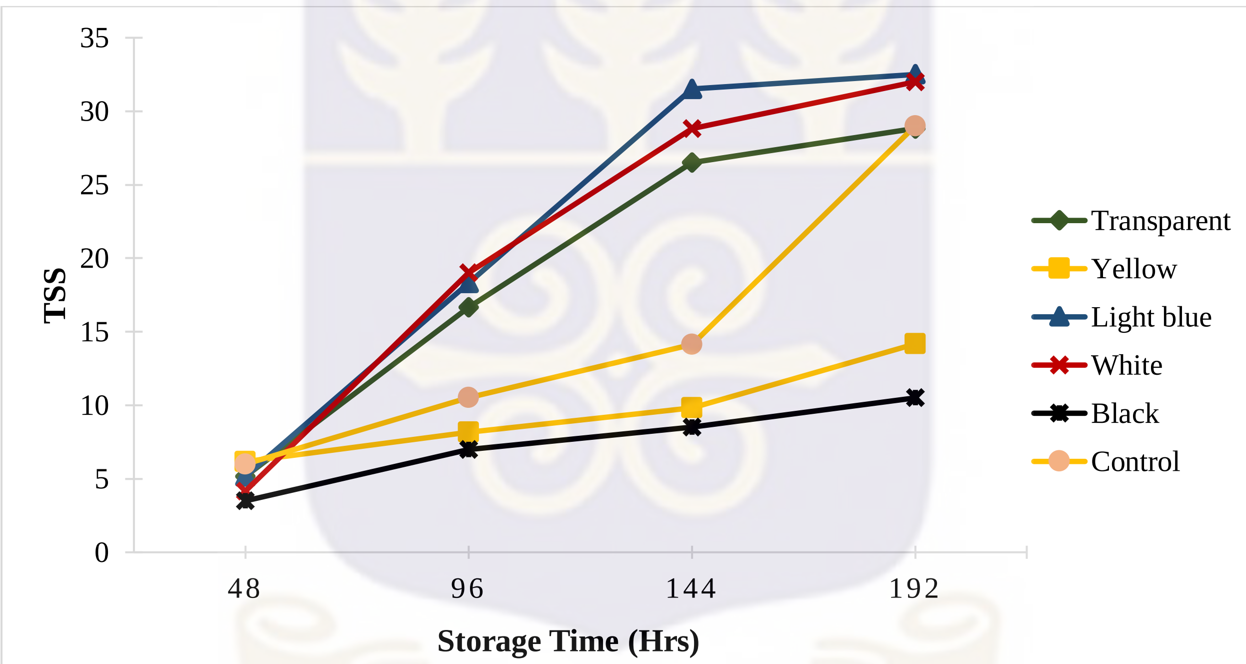


Figure 4.3.3 Changes in Total Soluble Solids (TSS) of plantains stored in different colors of polyethylene bags for up to 192 hours.

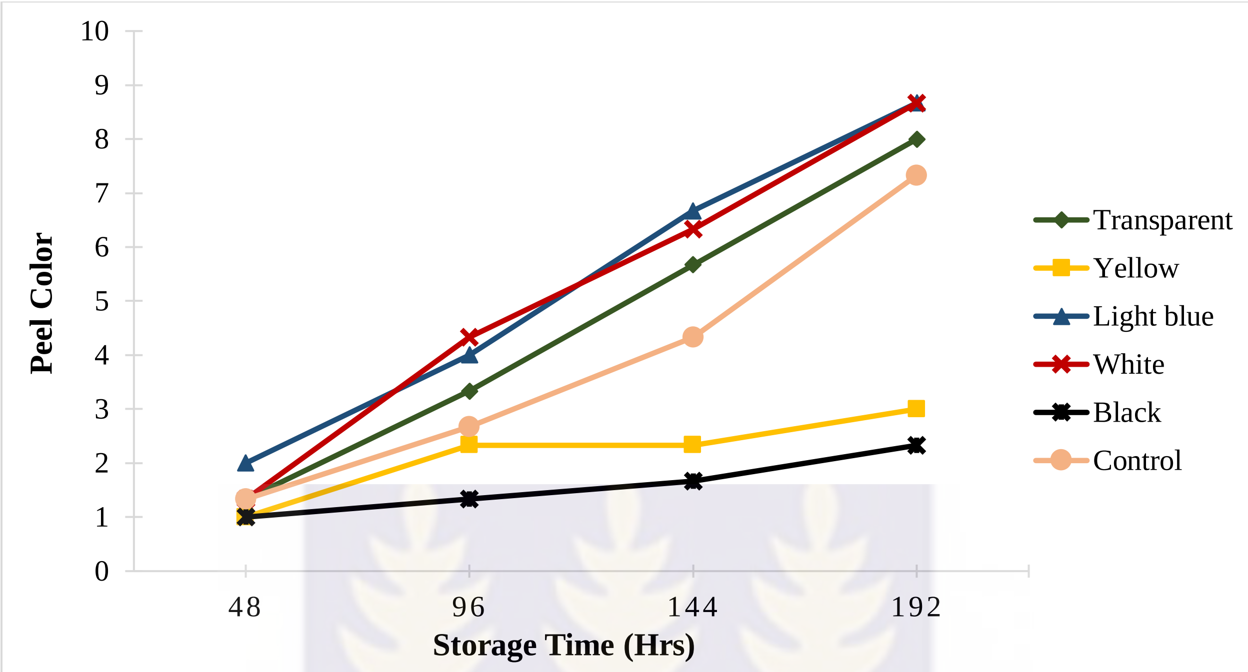


Figure 4.3.4 Changes in sensory Peel Color of plantain stored in different colors of polyethylene bags for up to 196 hours.

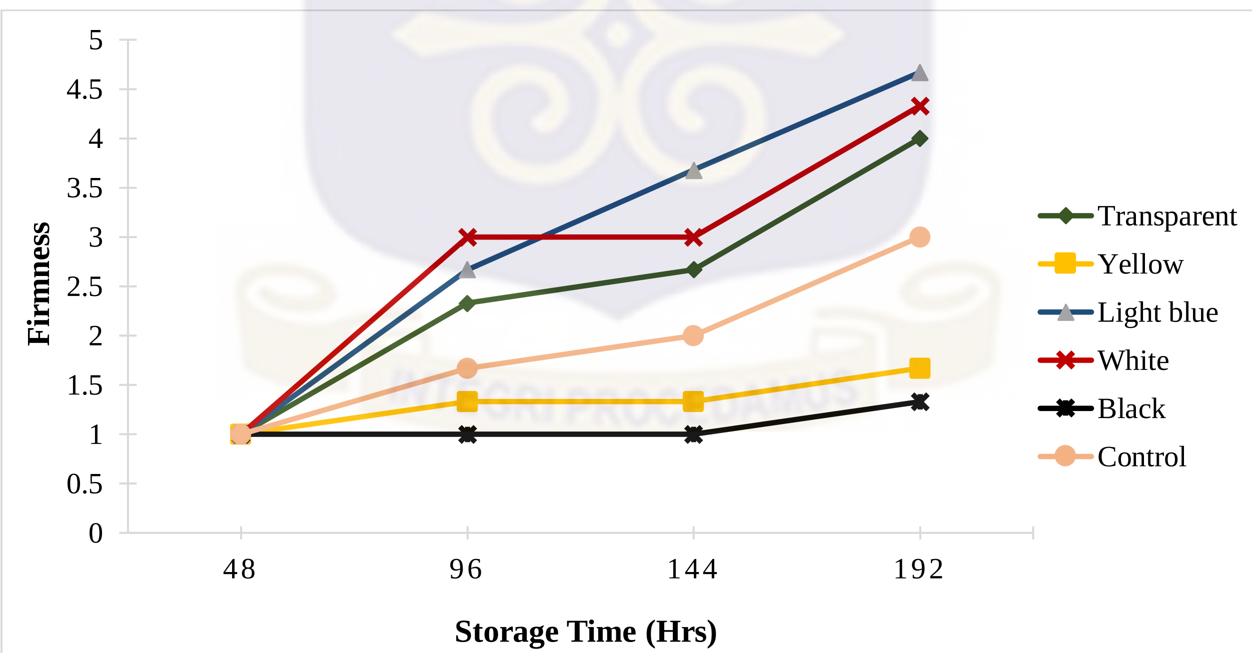


Figure 4.3.5 Changes in sensory Pulp Firmness of plantain stored in different colors of polyethylene bags for up to 192 hours.

It could therefore be deduced from these results that, ripening was delayed in the black polyethylene bag than for all the other colors of polyethylene bags while it was much faster in the light blue polyethylene bag.

Since all the factors that could have influenced the ripening rate in this experiment such as temperature and relative humidity (RH) (Bhande *et al.*, 2007) were the same for all treatments in this experiment, and also the thickness of the bags (which is a function of the gas transfer rate) (Hailu *et al.*, 2012), the observed differences in ripening rate could be attributed to the amount and the nature of light penetrating through this different colors of polyethylene bags unto the stored plantains. The fact that plantain, just like any other fruit or vegetable, is alive even after harvest (Sousa-Gallagher *et al.*, 2016) certain physiological and biochemical changes continue to take place which influence the texture, pigment breakdown/synthesis, sugar level and other attributes in the fruit (Anthon *et al.*, 2011). These changes have been found to be affected by factors such as the nature and intensity of light (McGuinness 2009; Gong *et al.*, 2015).

Gong *et al*. (2015) reported that, an LED blue light treatment at a temperature of 10˚C could induce fruit ripening in peach by increasing internal ethylene biosynthesis. Similarly, McGuinness (2009) also stated that, exposure of fruits to different wavelengths of light have the capacity to alter the ripening rate. Also, classic works on banana by Peacock and on tomato by Mpelkas and Kenyon as far back as 1972 reported that, exposure of banana fruits to light enhances senescence and shortens its pre-climacteric phase while a strong spectrum of light emitted from the blue and red regions has the ability to accelerate the ripening rate of tomato respectively. Obviously, the color and nature of light around the plantain inside these polyethylene bags in which they were stored corresponded with the individual colors of the bags. Therefore, judging from the above reports by these researchers, it is possible that the observed differences in the ripening rate were influenced by the nature of light that was available in the bags in which the fruits were stored. These findings also explain the faster ripening rate recorded by the plantain stored in the light blue color polyethylene bag. The slow ripening rate in the black polyethylene bag may also be due to a probable total darkness that engulfed the plantains and so there was little or no light available inside the black polyethylene bag and hence this slowed the ripening process.

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Plate 4.3.1 White, light blue and transparent polyethylene bags (from left to right) and the plantains stored in them after 192hrs (8days).

Plate 4.3.2 Black (left) and yellow (middle) polyethylene bags and the plantains stored in them and the control (right) after 192hrs (8days).

Again, the early ripening recorded in the white polyethylene bag than all the other colors of polyethylene bags based on the values recorded for starch content and reducing sugars (in Fig 4.3.1 and 4.3.2), the peel color (Fig 4.3.2) and the pulp firmness (Fig 4.3.3) up to the 96th hour, could be attributed to the fact that the white polyethylene bag had the ability to provide conditions that could hasten the commencement of the climacteric phase of the plantain stored in them. Generally, ripening hastens at this stage due to the autocatalytic increase in ethylene production and the sudden rise in respiration rate (Golden *et al*, 2014; Nordey *et al.*, 2016) but Sugri and Johnson (2009) in their work showed that when the factors that influence ripening are manipulated, it could affect how fast or how slow the climacteric phase commences which could either delay or hasten ripening. From the results, these conditions conducive for ripening which are the right temperature and humidity (Bhande *et al*., 2007) were probably achieved earlier in the white polyethylene bag than it was for all other colors and hence the ripening commencing faster in them than all the other bags.

For Titratable Acidity (Fig 4.3.6), another trend also worth noting was depicted. From the results, while some parameters (reducing sugars, peel color, pulp firmness and Total Soluble Solids) generally showed either a steady gradual increase or decrease (starch content) throughout the monitoring period, the Titratable Acidity (TA) for most of the samples rose to a point and then declined gradually. From Fig. 4.3.6, this trend is clearly shown for samples that were stored in the light blue, white and transparent polyethylene bags but for the control, yellow and black polyethylene bags, there was a seemingly steady increase in the TA up till 196 hours. This is because the samples that were stored in the yellow and black polyethylene bags did not reach the fully ripe (peak TA level) and overripe stages during the period when the samples were monitored as compared to the light blue, white and transparent polyethylene bags (also showing in Plates 4.3.1 and 4.3.2) and so the TA levels kept rising steadily till the 196 hours. A careful look at the trend of the TA levels for all the samples show that, the gradual increase in the TA generally occurred between the unripe stage and the fully ripe stage and the declining also happened between the fully ripe and the overripe stages. In the case of the control, it must have reached the fully ripe stage (the period for the gradual increase in TA level) on the 196th hour mark but because it was not monitored for any period thereafter, the decline in TA level is not showing in the graph and hence the seemingly steady increase in TA depicted in Fig 4.3.6.

Youryon and Supapvanich, (2017) as well as Siriboon and Banlusilp, (2004) reported similar trends in TA content in banana fruits during ripening and added that, the increase seems to positively correlate with peak ethylene production and thereafter drops gradually to lower levels. It then stands to reason that, titratable acidity in plantain tends to increase gradually as the fruit moves from the unripe to the fully ripe stage, the same period where respiration rate and ethylene production is also on the increase, and gradually decline as the plantain moves from fully ripe to the overripe stage through to rotting, and again, the same period when ethylene production and respiration rate is also decreasing. If this holds, then %TA levels in plantain could be used as an indicator in predicting ethylene production and respiration rates in plantains.

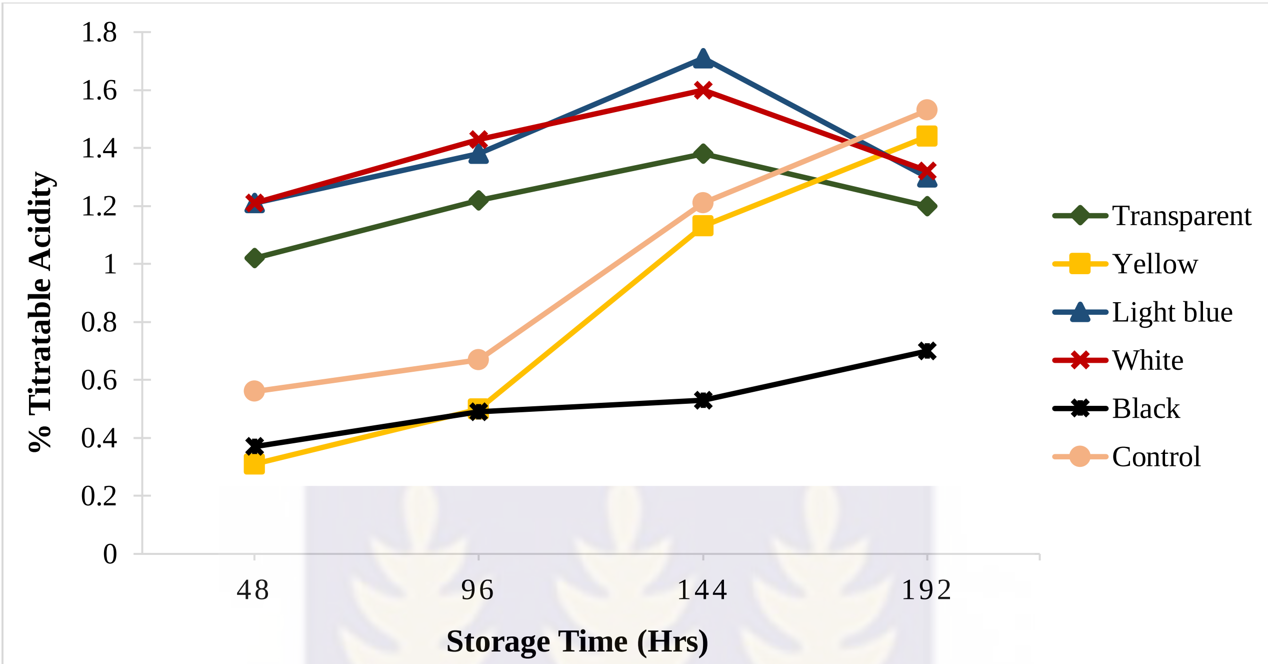

Figure 4.3.6 Changes in total titratable acidity (TA) of plantains stored in different colors of polyethylene bags for up to 192 hours.

4.4 Evaluating the use of shredded plantain pseudo-stem as a storage material for plantain after harvest.

Sensory assessment of pulp firmness and peel color (Fig 4.4.4 and Fig 4.4.5) as well as Total Soluble Solids (Fig. 4.4.1), Starch content (Fig. 4.4.2) and Reducing Sugar content (Fig. 4.4.3) were used to determine the rate of ripening of the plantain packaged in shredded plantain over a given period. From all the results, the shredded plantain pseudo stem showed an ability of delaying ripening while the combination of shredded plantain pseudo stem and potassium permanganate (both) hastened the ripening rate of the plantain compared to the control. Statistically, there were significant differences between treatments for all the days at 5% level of probability.

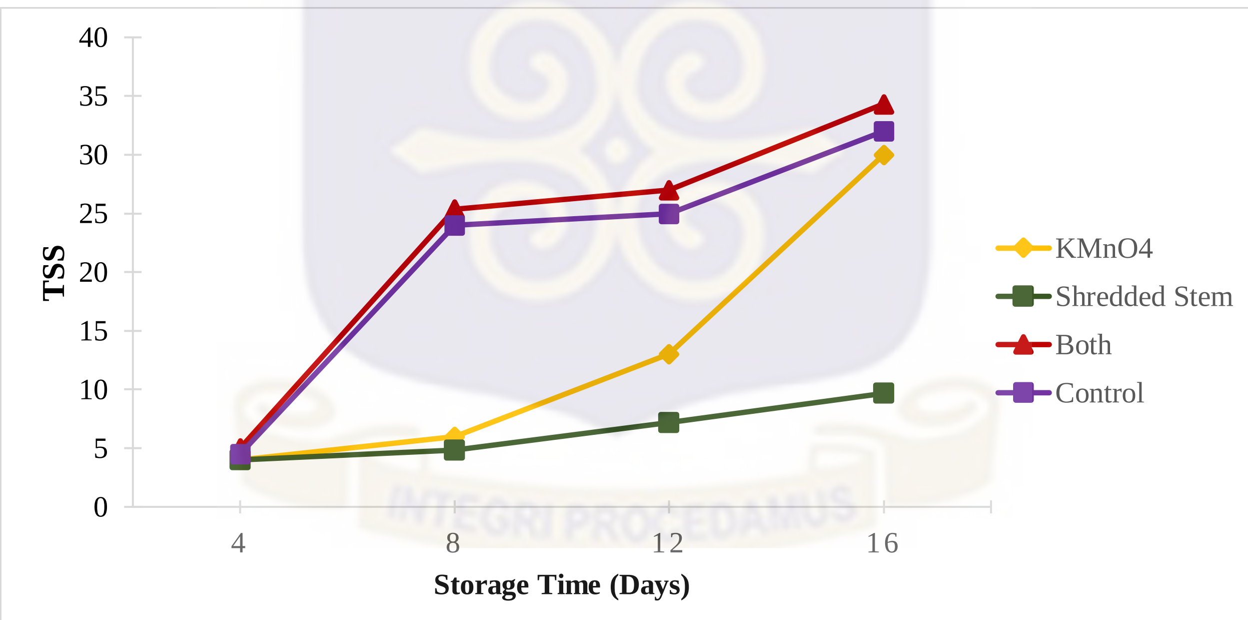

Figure 4.4.1 Changes in Total Soluble Solids (TSS) of plantain over a period of 16 days of being stored in four different ways; (i) with shredded plantain pseudo stem containing $KMnO_4$ (Both), (ii) $KMnO_4$ only, (iii) Shredded pseudo stem only, (iv) Control.

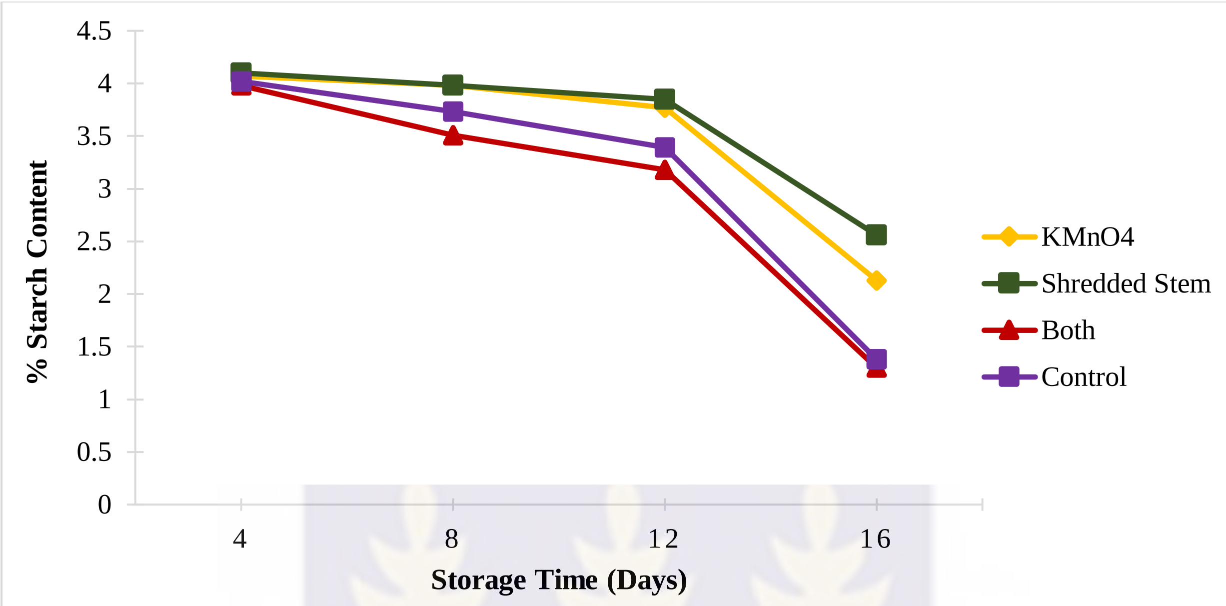

Figure 4.4.2 Changes in Starch content of plantain over a period of 16 days of being stored in four different ways; (i) with shredded plantain pseudo stem containing $KMnO_4$ (Both), (ii) $Kmno_4$ only, (iii) Shredded pseudo stem only, (iv) Control.

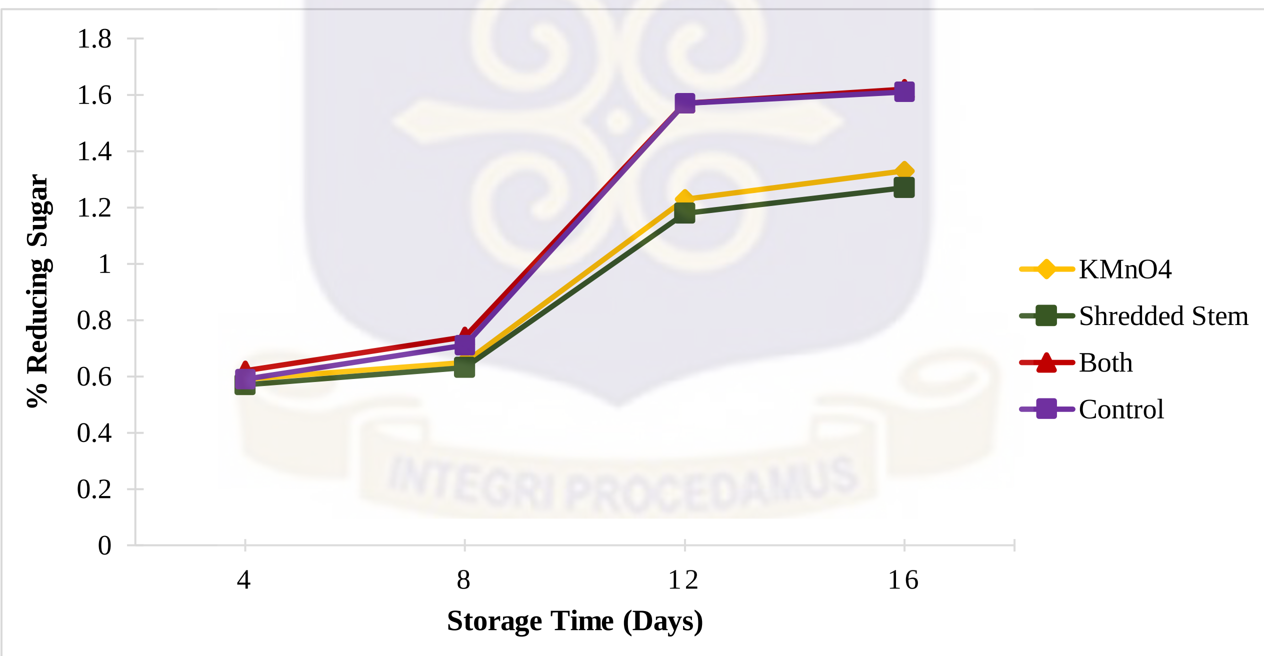

Figure 4.4.3 Changes in Reducing Sugars content of plantain over a period of 16 days of being stored in four different ways; (i) with shredded plantain pseudo stem containing $KMnO_4$ (Both), (ii) $KMnO_4$ only, (iii) Shredded pseudo stem only, (iv) Control.

Although not much have been specifically reported on the effect of plantain pseudo stem on fruit ripening behavior and shelf life of fruits presently, Johnson and Sugri (2009) reported the ability of sawdust of moisture content 50% increasing the pre-climacteric and post-climacteric storage life of *Apantu* (false horn plantain) to 26 and 32 days respectively under ambient conditions. They further attributed this efficiency of the moist sawdust being able (under tropical conditions) to increase the storage days to the ability of the ambient temperature, humidity and the velocity of the wind in creating the necessary cooling conditions that are below the ambient air temperatures. In this experiment, apart from the material used (shredded pseudo stem) which differs from theirs, all the conditions were similar, which makes it logical to also assert that same reasons might have been responsible for the observation in this experiment.

Also, the observed delay in ripening is possible to have resulted from the plantain pseudo stem having mineral elements or chemical composition that have the ability to oxidize the ethylene produced by the plantain. In that case, the plantain pseudo stem behaved as an ethylene absorbent just like the known potassium permanganate (Golden *et al.*, 2014). According to Glahan (2006) and Sharma *et al*. (2012), the main component of ethylene absorbents is potassium permanganate ($KMnO_4$) which prevents the deleterious effects of ethylene (C_2H_4) produced by fruits during ripening by oxidizing the ethylene to CO_2 and H_2O. This possibility is considered because, when Okelana (2001) and Akpabio *et al.* (2012) analyzed the plantain pseudo stem they found the pseudo stem to contain several mineral elements that included appreciable amounts of potassium. Okelana (2001) reported that the plantain pseudo stem contains about 6.2% of potassium (K), and at least 0.1% of other minerals like phosphorus (P), magnesium (Mg), sodium (Na) and calcium (Ca). The presence of these mineral elements in plantain pseudo stem together with other biochemical compounds may have the possibility of forming compounds that could give similar effects as the potassium permanganate used as ethylene absorbents in the plantain pseudo stem and hence causing the observed effect of delaying ripening in plantain.

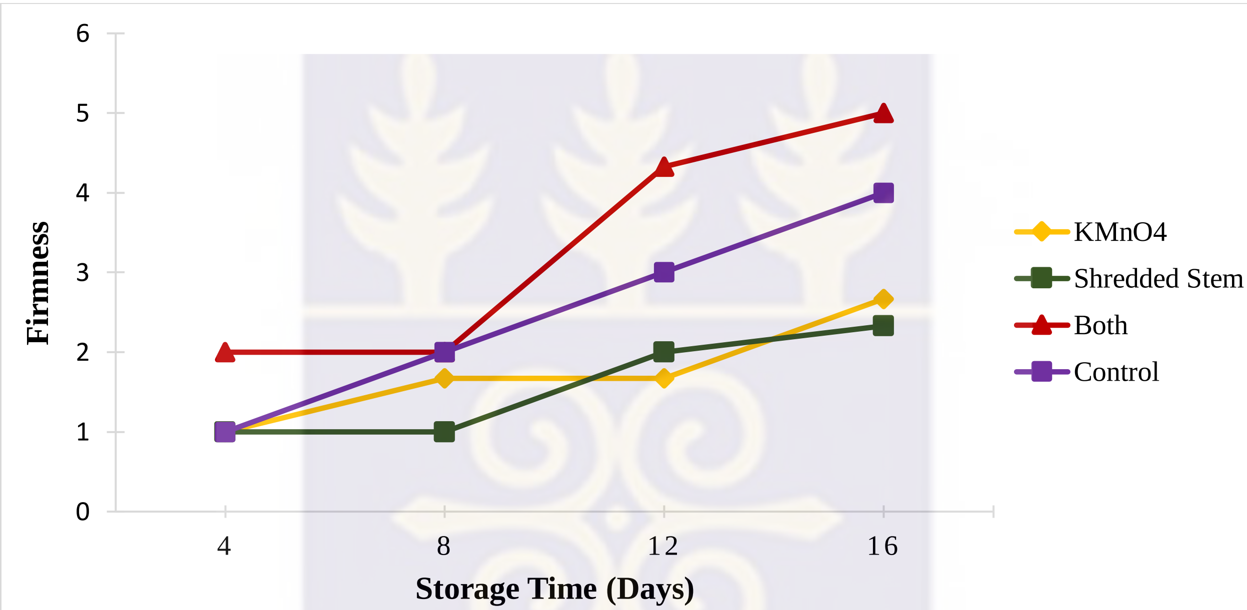

Figure 4.4.4 Sensory assessment of changes in Pulp Firmness of plantain over a period of 16 days of being stored in four different ways; (i) with shredded plantain pseudo stem containing $KMnO_4$ (Both), (ii) $KMnO_4$ only, (iii) Shredded pseudo stem only, (iv) Control.

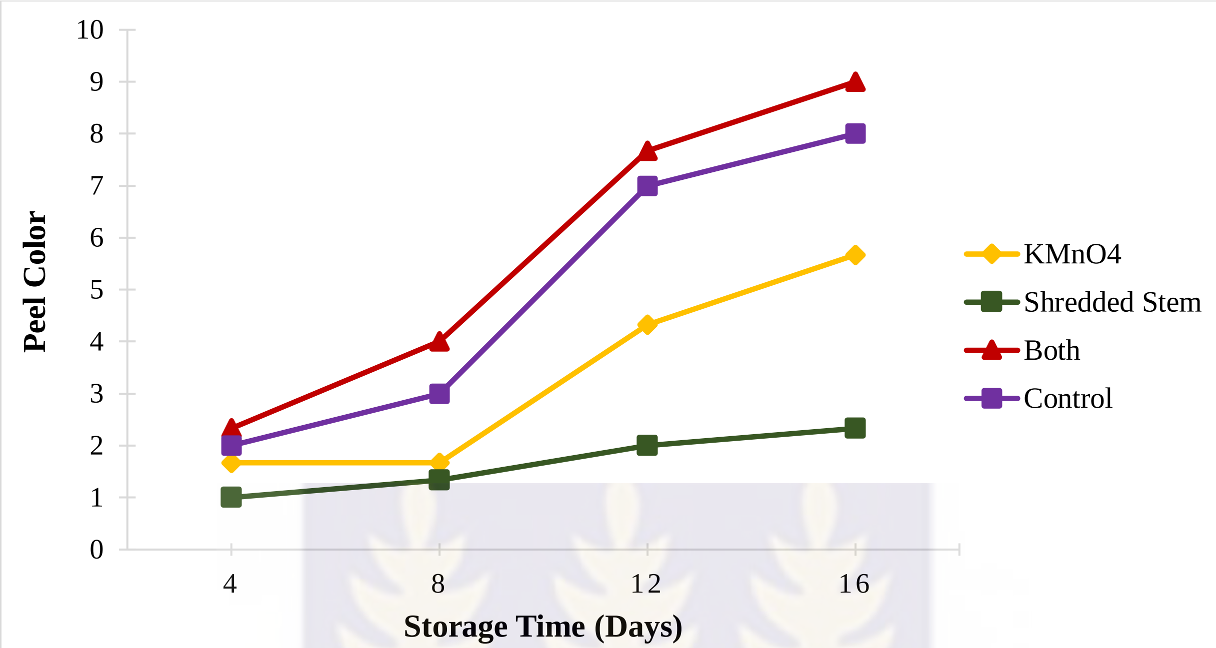

Figure 4.4.5 Sensory assessment of changes in Peel Color of plantain over a period of 16 days of being stored in four different ways; (i) with shredded plantain pseudo stem containing $KMnO_4$ (Both), (ii) $KMnO_4$ only, (iii) Shredded pseudo stem only, (iv) Control.

Also, this observation could have resulted from a possible competition for the limited oxygen (O_2) that was trapped in the polyethylene bag between the plantain fingers and the shredded pseudo stem which hampered respiration rate of the plantains and therefore delayed senescence of the plantain fingers in storage. This assertion is premised on the fact that, plantain is a fresh fruit, and as such requires oxygen for its respiration process (Fonseca *et al.*, 2002), which also leads to biochemical changes and initiation of ethylene production (Golden *et al*, 2014). As the shredded plantain pseudo stem begun to decompose, it was likely to have some molds (fungi) which are known to consume oxygen (Ofor *et al.*, 2010). Since both the fresh plantains and the shredded pseudo stem were put together in a polyethylene bag and sealed, the molds growth on the surface of shredded plantain pseudo stem might have consumed available oxygen in the polyethylene bag and therefore created a variation in the optimum O_2 level required by the plantain fingers during the storage period and hence the observed delay in ripening.

This phenomenon of lowering the O_2 levels a little below threshold and raising the CO_2 level to a little above optimum has been the basis for the success in modified atmosphere package (MAP) in extending the postharvest shelf life of fruit and vegetables (Sandhu and Singh, 2000; Dou-ShiJuan *et al.,* 2002 and 2003; Bhande *et al.*, 2007). Glahan (2006) reported the extension of the shelf life of Lychee to 18 days by storing it in a polyethylene bag with CO_2: O_2 flow rate ratio 5:5. Also, Kader *et al.* (1989) were able to establish that, by reducing O_2 concentration levels to below 8% and elevating CO_2 levels above 1% in the storage environment could extend the shelf life of fruits by preventing ripening and any associated changes in the fruit. The possibility of variation in optimum O_2 gas required by the plantains during storage being responsible for the delay in ripening rate of the plantain stored with the shredded pseudo stem could also not be ruled out in this case.

Plate 4.4.1 Plantain stored with $KMnO_4$ only (left) and Shredded pseudo stem only (right) for 16 days.

Plate 4.4.2 Plantain stored with Shredded pseudo stem and $KMnO_4$ (left) and the control (right) for 16 days.

Another important trend also worth discussing is that of the combination of the shredded pseudo stem and the $KMnO_4$ (Both) used as storage material for plantain. While the shredded pseudo stem and the $KMnO_4$ were individually able to delay ripening better than the control, their combination rather hastened the ripening rate than their individual rate. From the results also, temperature variation in the different bags could not have been responsible for this substantial difference in ripening rate (Kader, 2003; Bhande *et al.*, 2007) since the recorded temperatures in the polyethylene bags for all treatments uniformly ranged between 29 and 30˚C (±1) throughout the experimental period.

Here again, though there is not much literature specifically reporting on this observation, it could be postulated that this could have resulted from probably some of the mineral elements present in the plantain pseudo stem (Akpabio *et al.*, 2012; Okelana, 2001) having an adverse effect on potassium permanganate ($KMnO_4$) or interacting with it to form a different compound (s) that alter their individual effects on ripening. This is because, when Bhattacharjee and Dhua (2017) treated bitter gourds with Silica gel-permanganate and Celite-permanganate mixture under ambient storage conditions of 27.2-31.4˚C and 69-72% RH, they recorded gradual rise in spoilage as early as after the 4th day. Also, when Sharma *et al.* (2012) used different combinations of potassium permanganate ($KMnO_4$) together with other materials namely; potassium permanganate ($KMnO_4$) only in a sachet, potassium permanganate absorbed into chalk and potassium permanganate absorbed into a newspaper to extend the postharvest shelf life of Japanese plums (*Prunus salicina* Lindell) cv. Santa Rosa the results varied from 3-4 days to between 9-12 days at uniform storage temperature of 38˚C±2 and RH of 68%±4. The result at the end of their study showed that, the potassium permanganate only in sachet had a better performance in terms of all the quality parameters measured for preservation, than that of the potassium permanganate absorbed into chalk and newspaper. It could be deduced from these reports that, potassium permanganate may be effective as an ethylene absorbent when used alone but becomes less effective when its structure is altered or absorbed into a material, possibly due to an interaction with the material. Therefore, in the study, using the potassium permanganate together with the shredded plantain pseudo stem reduced the effectiveness of both treatments in delaying ripeness in the plantain through a possible interaction which is unascertained in this research.

Again, just like it was observed in the experiment to evaluate the effects of different colors of polyethylene sheets on the ripening behavior (specific objective 3) of this research, percentage Titratable Acidity (TA) in the plantain in this experiment also increased from the beginning of the experiment to the point when fruits were fully ripe and then started declining sharply as the fruits moved into the overripe stage (Fig 4.4.6). This could be thought of as a confirmation for the observed trend in objective three.

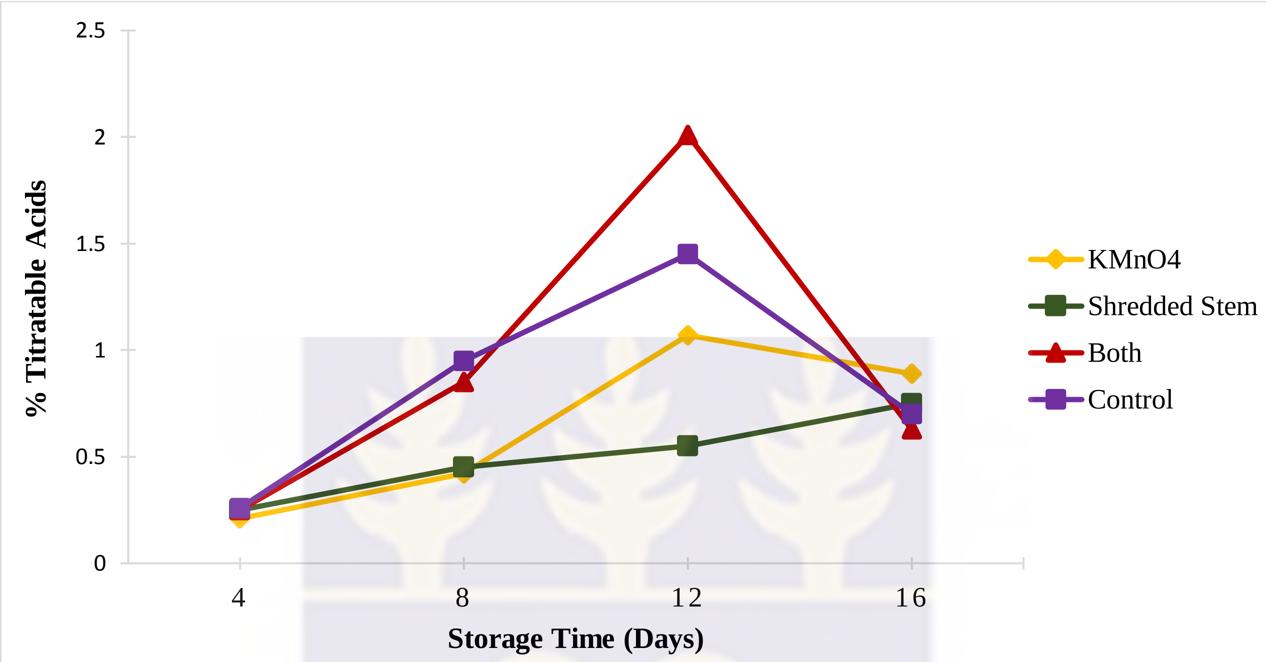

Figure 4.4.6 Changes in Titratable acidity (TA) of plantain over a period of 16 days of being stored in four different ways; (i) with shredded plantain pseudo stem containing $KMnO_4$ (Both), (ii) $KMnO_4$ only, (iii) Shredded pseudo stem only, (iv) Control.

4.5 Determining the influence of Calcium carbide (CaC_2) and corn dough on the ripening behavior on plantain.

In this experiment, the results from trying to induce ripening in plantain by storing them with corn dough and calcium carbide for 24 hours showed that, no ripening occurred in the corn dough treatment and the control but there was ripening in the calcium carbide only treatment as well as the calcium carbide and corn dough (both) treatments.

The statistical analysis of the results from this experiment showed that there was significant difference in titratable acidity (TA), starch content, reducing sugars, total soluble solids (TSS) and peel color for all treatments but no significant difference in the pulp firmness at $P \leq 0.05$. The results are presented in Table 4.5.

Using these measured parameters as indicators of ripening in the plantain samples, it was clear that for artificial ripening of plantain to be achieved within 24 hours, calcium carbide treatment or any treatment combination that included calcium carbide, as in the case of the 'both' (calcium carbide and corn dough) was needed. Use of corn dough alone cannot bring about ripening of plantain within 24 hours. These results compare favorably with Sogo-Temi *et al.* (2014), Gunasekara *et al.* (2015) and Gandhi *et al.* (2016).

Table 4.5 Effects of using CaC_2 and Corn dough as ripening agents on the ripening behavior of plantain.

Treatment	TTA(%)	Starch(%)	RS(%)	TSS	Peel color	Pulp firmness
Corn dough	$0.28{\pm}0.01^c$	$3.83{\pm}0.04^b$	$0.57{\pm}0.00^c$	$8.00{\pm}0.00^c$	$1.67{\pm}0.58^b$	$1.00{\pm}0.00^a$
CaC_2	**$0.60{\pm}0.04^a$**	$3.66{\pm}0.02^c$	$0.65{\pm}0.00^b$	$13.00{\pm}0.00^b$	**$6.33{\pm}1.16^a$**	$1.67{\pm}0.58^a$
Corn dough & CaC_2	$0.50{\pm}0.01^b$	$3.61{\pm}0.03^c$	**$0.69{\pm}0.00^a$**	**$15.33{\pm}0.58^a$**	**$5.67{\pm}0.58^a$**	$1.67{\pm}058^a$
Control	$0.20{\pm}0.01^d$	**$4.07{\pm}0.01^a$**	$0.54{\pm}0.01^d$	$4.33{\pm}0.29^d$	$1.00{\pm}0.00^b$	$1.00{\pm}0.00^a$

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

For the calcium carbide only and the combination of calcium carbide and corn dough (both) treatments there were no significant differences between the physical quality attributes (peel color and pulp firmness) as shown in Table 4.5. The differences in titratable acidity (TA), reducing sugars, and total soluble solids (TSS) were however statistically different at P≤0.05.

This outcome depicts that both treatments (calcium carbide only and a combination of calcium carbide and corn dough) could be used to achieve similar results, especially in the peel color (Plate 4.5.1) which is the main parameter of interest to the market women since peel color is a major attribute that influences consumers' choice.

Comparing the state of the samples for the calcium carbide only treatment and the calcium carbide and corn dough (both) treatment, it could therefore be inferred that, probably the two main reasons why the market women add the corn dough are; (i) either to mask the scent of the calcium carbide on the plantain after being used to enhance the ripening or (ii) to help raise the temperature within the sack which could also aid early ripening. This is because, plantain fingers from the calcium carbide and corn dough treatment did not have the strong scent of the carbide on them as compared to the ones from calcium carbide only treatment. Also, while the three consecutive temperature measurements taken on a five-minute interval for the control and the calcium carbide only treatments ranged between 31˚C to 29˚C for all their replications, that of the corn dough only and the combination of calcium carbide and corn dough (Both) treatments recorded quite high temperatures of 34˚C which later dropped to 32˚C. The recorded high temperatures in the sacks that had the corn dough treatments must have resulted from the heat generated by the fermentation process that was ongoing in the corn dough (Malherbe *et al.*, 2007; Murasawa and Koseki, 2015) which may have also influenced the ripening process. This notwithstanding, it is also important to state that, though there was a general rise in temperature for all the replications that had corn dough treatment, there was no hastened ripening in the corn dough only treatment. This occurrence therefore points out the fact that, yes, there might have been some level of temperature rise caused by the use of the corn dough but the amount of heat generated in the sack by the fermenting corn dough alone could not have had any significant influence on the faster ripening rate achieved in the plantain. This makes it safe to further assert that, the observed overnight ripening was more dependent on the use of the calcium carbide than the use of the corn dough.

Therefore, from the observed results, it could be concluded that, the main reason why the market women spend extra money to use the corn dough in addition to the calcium carbide is because they might have either consciously or unconsciously realized this ability of the corn dough to mask the scent of the calcium carbide on the plantains and hence, they use it to prevent customers from smelling the calcium carbide on the ripe plantains in order to deceive unsuspecting consumers.

Plate 4.5.1 Two days old plantains stored with CaC_2 (left) and a combination corn dough and CaC_2 (right) for 24 hours (picture taken 5 hours after removing plantains from sack).

Plate 4.5.2 Two days old plantains stored with corn dough (left) and the control (right) for 24 hours (picture taken 5 hours after removing plantains from sack).

Again, although there was a significant difference in almost all the quality parameters (titratable acidity, starch content, reducing sugars, total soluble solids and peel color) considered in this experiment, there was no significant difference in pulp firmness for all treatments as shown in Table 4.5. This means that though the peel color (and other chemical attributes) of the plantain could be changed overnight, its texture/firmness will still be as hard as that of an unripe plantain, a quality attribute that may not be appealing enough to consumers. Suman *et al.* (2011) and Gandhi *et al.* (2016) in similar works reported that, fruits ripened with calcium carbide can develop good peel color but their quality in terms of softness and flavor suffers. Hakim *et al.* (2012) also reported that, even though the use of artificial agents has the capacity to give a more desirable color in terms of ripening, than the naturally ripened fruits, their quality in terms of health hazards may be questionable.

Apart from the inability of the calcium carbide to give desirable ripening qualities as compared to natural ripening procedures, its adverse potential on human life has been established in the fact that it is a known carcinogenic substance and its use on any food material is strictly banned (Rahman *et al.*, 2008). It also contains compounds like phosphorus and traces of Arsenic that are hazardous to human health (Wasim and Dhua, 2010; Suman *et al.*, 2011). Per *et al.* (2011) also reported the dangerous effects of the acetylene gas produced by the calcium carbide on the neurological system in causing prolonged hypoxia which culminates into many health complications.

These effects have made the international rule on the prevention of Food Adulteration Rules (Act 1954 and 1955) to place a ban on the use of calcium carbide on food materials and so fruit handlers need to be educated on this regulation. It is important that local handlers of fruits like plantain and banana and others are therefore encouraged to desist from the use of calcium carbide on fruits or any food material since apart from changing the peel color of the fruit, it does not really give any benefits but poses many dangers.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

The conclusions are stated as per the objectives of the study.

The findings from the survey conducted have shown that the major problems associated with the handling of plantain by order of intensity are inefficient distribution or transportation system, difficulties in delaying ripening, lack of proper storage facilities (both at the farm gates and on the markets), packaging problems, lack of proper ripening techniques when the need arises and financing.

The results from the experiment involving the different forms of packaging showed that to minimize the level of mechanical damage that predisposes the plantain to spoilage, it will be necessary to introduce some form of packaging during the transportation of plantain from the production centers. This is even more needed due to the bad state of the roads.

The color of polyethylene bag used to store matured green plantain can greatly influence its ripening behavior. Specifically; to delay ripening packaging in black colored polyethylene bag can be used to extend the green life and slow down the ripening process whereas using the blue colored polyethylene could hasten total ripening process. To kick start the initiation of the ripening process, packaging in a white colored polyethylene bags would be useful.

The shredded plantain pseudo stem as a storage material for plantain could preserve the green state of plantain for a longer period (at least 16 days), even better than the widely known potassium permanganate but the combination of the shredded plantain pseudo stem and the potassium permanganate as a storage material for plantain therefore, could rather hasten the ripening.

Also, from this study it could be confidently reported that, corn dough does not cause ripening in plantain within 24 hours after using it to store the plantain, as claimed by some of the market women interviewed in this study. It is only calcium carbide that has the ability to do that.

Finally, it is now evident from this research that, cheap, harmless and locally available materials and methods could be used to improve upon the quality of plantain in areas such reducing the mechanical damage and the level of spoilage during transportation and storage (delay or hasten ripening as the case may be).

5.2 Recommendations

From the findings of this study, it is recommended that;

i). Further research to explain the mechanism by which shredded plantain pseudo is able to delay ripening in plantain is required.

ii). Also, studies into why storing plantain with a combination of potassium permanganate and shredded plantain pseudo stem hastens ripening whereas, when they are used separately, they both delay ripening need to be conducted.

iii). Stringent efforts should be made by mandated authorities toward preventing the use of calcium carbide in ripening since the market women are still using it, despite the ban.

6.0 REFERENCES

Abiodun-Solanke, A.O. and Falade, K.O. (2010). A review of the uses and methods of processing banana and plantain (Musa spp.) into storable food products. Technology, F. *9*(2)

Action Contre la Faim (ACF) (2014). Potharvest losses and strategies to reduce them. Technical Paper; Scientific and Technical Department

Adeniji, T. A., Tenkouano, A., Ezurike, J. N., Ariyo, C. O., and Vroh-Bi, I. (2010). Value-adding post-harvest processing of cooking bananas (Musa spp. AAB and ABB genome groups). Afri J Biotechnol, 9(54), 91359141. Retrieved from http://www.academicjournals.org/AjB/PDF/pdf2010/2 9Dec%20Special%20Review/Adeniji%20et%20al.pdf

Adewole, M.B and Duruji, R.W. (2010). Quality assessment of plantain (Musa paradisiacal L.) as affected by different ripening methods. African Journal of Biotechnology, 9(38):6290-6293

Adewumi, M. O., Ayinde, O. E., Falana, O. I. and Olatunji, G. B. (2009). Analysis of Post-Harvest losses among plantain/Banana (Musa Spp.L.) marketers in Lagos State, Nigeria. Nigerian Journal of Agriculture, food and Environment. 5(2-4): 35–38

Adu-Amankwa Pearl, A., Agyemang Boateng Bernard, (2011). Postharvest status of plantains in some selected markets in Ghana. Afri J Agri Res., 1:006-010

Aina O. S., Ajijola S., Bappah M. T., Ibrahim I. and Musa I. A. (2012): Economic Analysis of Plantain Marketing in Odigbo Local Government Area of Ondo State, Nigeria. Global Advanced Research Journal of Agricultural ScienceVol.1(5) pp.104-109, July, 2012

Ajayi, A. R. and Mbah, G.O. (2003). The major causes of economic losses to banana and plantain fruits women-marketers in Ebonyi state, Nigeria. p.138–143. In: A. S. Fasina, A. O.

Ajayi, A.R and Mbah, G.O (2007). Identification of indigenous ripening technologies of banana and plantain fruits among women-marketers in Southeastern Nigeria. Journal of Agriculture, Food, environment and Extension, 6(2):60-66

Aked, J. (2000). Fruits and vegetables, In: D. Kilcast and P. Subramaniam (eds), The Stability and Shelf-Life of Food, Woodhead Publishing Ltd, Cambridge, pp. 249± 278

Akinyemi, S. O. S., Aiyelaagbe, I. O. O and Akyeampong, E. (2010). Plantain (Musa spp.) Cultivation in Nigeria: a Review of Its Production, Marketing and Research in the Last Two Decades. Proc. IC on Banana and Plantain in Africa Eds.: T. Dubois *et al*. Acta Hort. 879, ISHS 2010

Akpabio, U. D., Udiong, D. S., & Akpakpan, A. E. (2012). The Physicochemical Characteristics Of Plantain. Adv. in Nat. Appl. Sci., 6(2): 167-172, 2012

Albanese, D., Cinquanta, L., Di Matteo, M. (2007). Effects of an innovative dipping treatment on the cold storage of minimally processed Annurca apples. Food Chemistry, v. 105, p. 1054-1060. http://dx.doi.org/10.1016/j.foodchem.2007.05.009

Ali, M. B. and Abu-Goukh, A. A. (2005). Changes in pectic substance and cell wall degrading enzymes during tomato fruit ripening. University of Khartoum Journal of Agricultural Sciences, 13(2): 202-223

Alliance for a Green Revolution in Africa (AGRA) (2014). Establishing the status of postharvest losses and storage for major staple crops in eleven African countries (Phase II). AGRA: Nairobi, Kenya

Anthon, G. E., Lestrange, M., & Barrett, D. M. (2011). Changes in pH, acids, sugars and other quality parameters during extended vine holding of ripe processing tomatoes. Journal of the

Science of Food and Agriculture, 91(7), 1175–1181. http://doi.org/10.1002/jsfa.4312

Ayanwale A. B, Fatunbi A. O and Ojo M (2016). Innovation Opportunities in Plantain Production in Nigeria. Guide Book 1. Forum for Agricultural Research in Africa (FARA), Accra Ghana

Bhande, S. D., Ravindra, M. R., & Goswami, T. K. (2007). Respiration rate of banana fruit under aerobic conditions at different storage temperatures, *87*, 116–123. http://doi.org/10.1016/j.jfoodeng.2007.11.019

Bhattacharjee, D., & Dhua, R. S. (2017). Influence of Ethylene Absorbents on Shelf Life of Bitter Gourd (Momordica charantia L .) Fruits during Storage, *6*(5), 1553–1563

Boning, C. R. (2006). Florida's best fruiting plants. Pineapple Press Inc., Florida

Cameron, A.C., P. C. Talasila and D.W. Joles. (1995). Predicting film permeability needs for modified-atmosphere packaging of lightly processed fruits and vegetables. HortScience 30(1):25-34

Chaves, M. A., Bonomo, R. C. F., Silva, A. A. L., Santos, L. S., Carvalho, B. M. A., Souza, T. S., … Soares, R. D. (2007). Use of Potassium Permanganate in the Sugar Apple Post-Harvest Preservation. *Uso De Permanganato De Potasio En La Preservaci?N Post-Cosecha De Frutas De Chirimoya. Ciencia Y Tecnologia Alimentaria*, *5*(5), 346–351 http://doi.org/10.1080/11358120709487711

Chessman, E. E. (1948). Classification of the bananas III. Critical notes on species c. *Musa paradisiaca* L. and *M. sapientum.* Kew Bulletin No. 2, 1948: 145-153

Chitarra, M. I. F., Chitarra, A. B. (2005). *Pós-colheita de Frutas e Hortaliças: fisiologia e manuseio. 2. ed. Lavras: UFLA, 783 p*

Clendennen, S. K and May, G. D. (1997). Differential gene expression in ripening banana fruit.

Plant Phsysiol, **115**, 463

Constantine, D. (2004). The nomenclature of the genus Musa <http://www.users.globalnet.co.uk/~drc/Nomenclature. htm>

Constantine, D., Rossel, G. (2001). The *Musaceae*: An annotated list of the species of *Ensete*, *Musa* and *Musella*. http://www.users.globalnet.co.uk/drc/index.htm

Cropley, J. and Morriss, K. (1993)**.** Report on a visit to Ghana to collect baseline data on starch-staplesystems in. West Africa, with special reference to plantains Natural. Resources Institute, Chattam,U.K

Dadzie, B. K., and Ochard, J. E. (1997). Post-harvest criteria and methods for the routine screening of banana/plantain hybrids. INIBAP Technical Guidelines 2. International Network for the improvement of banana and plantain (INIBAP), Montpellier

Daniells, J., Jenny, C., Karamura, D., Tomekpe, K. (2001). *Musalogue: A Catalogue of Musa Germplasm. Diversity in the Genus Musa.* International Network for the Improvement os Banana and Plantain, Montpellier, France, available online at http://bananas.bioversityinternational.org/files/files/pdf/publications/musalogue2.pdf.

Daniells, J. W. (2003). Bananas and plantains, 372–378

DeLanghe, E. (1995). Banana and Plantain: the earliest fruit crops? International Network for the Improvement of Banana and Plantain, Montpellier, France, available online at http://bananas.bioversityinternational.org/files/files/pdf/publications/ar95_en.pdf

De Long, J. M., Prange, R. K. (2003). Storage. In: Thomas B, Murphy DJ, Murray BG (eds) Encyclopedia of applied plant sciences. Elsevier Ltd, Oxford/San Diego. doi: 1 0.1016/ B0-12-227050-9/00346-X

Dou-ShiJuan, Chen-KunSong, LuJunLiang, Zheng JT (2002). The storability and its regulatory mechanism of Huanghua pear (Pyrus pyrifolia Nakai.) fruit as influenced by postharvest treatments. Agric Sci China 1:1238–1245

Dou-ShiJuan, Chen-KunSong, LuJunLiang, Zheng JT (2003). Effects of different postharvest treatments on storage of Huanghua pear fruit (Pyrus pyrifolia Nakai) and its physiological basis. *Scientia Agricultura Sinica 36:82–88*

Dzomeku, B. M., Dankyi, A. A., & Darkey, S. K. (2011). Socioeconomic Importance of Plantain Cultivation in Ghana. International Journal of Plant Physiology and Biochemistry, 21(2), 1–6. http://doi.org/10.5897/IJPPB2015.0235

Dzomeku, B. M., Sarkordie Addo, J., Darkey, S. K., Bam, R. K., & Wuensche, J. (2016). Evaluating postharvest characteristics of Apantu (Local False Horn) plantain for harvest indices determination. International Journal of Plant Physiology and Biochemistry, *8*(1), 1–6. http://doi.org/10.5897/IJPPB2015.0235

Ekunwe, P. A., & Ajayi, H. I. (2010). Economics of Plantain Production in Edo State Nigeria. Research Journal of Agriculture and Biological Sciences, *6*(6), 902–905. Retrieved from http://www.aensiweb.com/rjabs/rjabs/2010/902- 905.pdf

ELkashif, M. E.; Elamin, O. M. and Ali, S. A. (2005). Effect of packaging method and storage temperature on quality and storability of four introduced banana clones. Gezira Journal of Agricultural Science, 3(2): 185-195

El-ramady, H. R., Domokos-szabolcsy, É., Abdalla, N. A., Taha, H. S., & Fári, M. (2015). *Postharvest Management of Fruits and Vegetables Storage*. http://doi.org/10.1007/978-3-319-09132-7

Evans School Policy Analysis and Research (EPAR), (2013): Banana and Plantain Value Chain: West Africa, EPAR Brief No. 239, August 20, 2013

Fagundes, C., Carciofi, B. A. M., Monteiro, A. R. (2013). Estimate of respiration rate and physicochemical changes of fresh-cut apples stored under different temperatures. Food Sci. Technol., Campinas. Jan-Mar. *33*(1), 60–67

Faturoti B. O., Madukwe, M. C., Tenkouano, A and Agwu, A. E. (2007). A review of policy acts and initiative in plantain and banana innovation system in Nigeria. African Journal of biotechnology 6(20), 2297-2302

FAO-Food and Agriculture Organization (2014). FAOSTAT Rome, Italy: http://faostat. external.fao.org/. Accessed on 20th April, 2017

FAO, (2014). (Food and Agriculture Organization). Food and agriculture indicators ESSA

FAO, (2013). Food wastage footprint: Impacts on natural resources

FAO (2011). Global food losses and waste: Extent, Causes and Prevention

Ferris, R. S. B. (1997). Post-harvest physiology of plantain and plantain. IITA Research Guide (62). Ibadan. at http://www.iita.org/inf.trn_mat/irg62.html

Fonseca, S. C., Oliveira, F. A. R., & Brecht, J. K. (2002). Modelling respiration rate of fresh fruits and vegetables for modified atmosphere packages: A review. Journal of Food Engineering, 52(2), 99–119. http://doi.org/10.1016/S0260-8774(01)00106-6

Gandhi, S., Mahak, S., & Barkha, B. (2016). Comparative Study on the Ripening Ability of Banana by Artificial Ripening Agent (Calcium Carbide) and Natural Ripening Agents. Indian Journal of Nutrition, *3*(1), 1–5

Glahan, S. (2006). Extending the shelf life of lychee using different CO2:O2 ratios and an ethylene absorbent in polyethylene bags. Journal of Agricultural Technology 2(1): 121-135

Golden, K. D., Williams, O. J., & Dunkley, H. M. (2014). Ethylene in postharvest technology: a reviev. Asian Journal of Biological Science 7. Retrieved from http://knowledgiascientific.com

Gong, D., Cao, S., Sheng, T., Shao, J., Song, C., Wo, F., … Yang, Z. (2015). Effect of blue light on ethylene biosynthesis, signalling and fruit ripening in postharvest peaches. *Scientia Horticulturae*, *197*, 657–664. http://doi.org/10.1016/j.scienta.2015.10.034

Gowen, S., (1995). Bananas and Plantains. Chapman and Hall, London (http://www.turbana.com/index.htm). Benefits of the banana

Gray J, Picton S, Shabbeer J, Schuch W, Grierson D. (1992). Molecular biology of fruit ripening and its manipulation with antisense genes. Plant Mol Biol. 19(1):69–87. [PubMed]

Grolleaud, M. (2002). Post-harvest losses: discoverying the full story. Overview of the phenomenon of losses during the post-harvest system. Rome, Italy: FAO, Agro Industries and Post-Harvest Management Service (AGSI)

Gunasekara, S. R. W., Hermamali, K. K. G. U., Dayananada, T. G. and Jayamanne, V. S. (2015). Post Harvest Quality Analysis of " EMBUL " Banana Following Artificial Ripening Techniques. Int. J. of Sci, Environ & Techno, Vol. 4, No 6, 2015, 1625 – 1632

Hakim, M.A; Obidul Huq, A.K, Alam, M.A, Khatib, A, Saha, B.K, Formuzul Haque, K.M and Zaidul, I.S.M (2012). Role of health hazardous ethephone in nutritive values of selected pineapple, banana and tomato. Journal of Food, Agriculture and Environment 10(2):247-251

Hailu, M., Seyoum Workneh, T., & Belew, D. (2012). Effect of packaging materials on shelf life and quality of banana cultivars (Musa spp.). Journal of Food Science and Technology, 51(11), 2947–2963. http://doi.org/10.1007/s13197-012-0826-5

Hassan, A. and Hassan, E. (2014). Potassium permanganate and packing types impacts on postharvest quality and storage period of quince fruit (Cydonia Oblonga Mill). Int. J. Adv.

Lif. Sci., 7(2): 267-275

Hassan, M. K., Chowdhury, B.L.D. and Akhtar, N. (2010). Post harvest loss assessment: A study to formulate policy for loss reduction of fruits and vegetables and socioeconomic uplift of the stakeholders. Final report (PR 8/08). 16.pp. 166-167

Hodges, R. J., Buzby, J. C, Bennett, B. (2011). Postharvest losses and waste in developed and less developed countries: opportunities to improve resource use. Journal of Agricultural Science, 2011 (149), 37-45, . © Cambridge University Press 2010

Hoehn, E., Prange, R. K. and Vigneault, C. (2009). Storage technology and applications. In: E M Yahia (ed.), Modified and Controlled Atmospheres for Storage, Transportation, and Packaging of Horticultural Commodities, Woodhead Publishing Ltd, Cambridge, pp. 17±50

Horry, J. P., Arnaud, O. E., Crouch, J. H., Ferris, R. S. B., Jones, D. R., Mateo, N., Picq, C., Vuylsteke, D. (1997). Banana and Plantain. Chapter 6. In: D Fuccillo, L Sears, P Stapleton, eds. Biodiversity in Trust. Conservation and Use of plant Genetic Resources in CGIAR Centres. Cambridge University Press, Cambridge. pp 67-81

Hussain, I. M., Asif, M., Ahmad, M., Khan and I. Shakir. (2004). Effect of Uni-packaging on the postharvest behavior of citrus fruits in NWFP. Pak. J. Nutr., 3 (6): 336-339

International Institute for Tropical Agriculture (IITA) (2009). Banana and Plantain Systems, R4D Fact Sheet

Islam, K., Khan, M. Z. H., Sarkar, M. A. R., Absar, N., and Sarkar, S. K. (2013). Changes in Acidity , TSS , and Sugar Content at Different Storage Periods of the Postharvest Mango (Mangifera indica L .) Influenced by Bavistin DF, *2013*

James, C.S. (1995). Analytical Chemistry of Foods. 1st Edn., Chapman and Hall, New York, ISBN: 978-1-4613-5905-0, Pages: 178

Jobling, B. J. (2001). Correct cool chain management is essential for all fruit and vegetables

John, P and Marchal, J. (1995). Ripening and biochemistry of the fruit. In: S Gowen (Ed) Banana and plantain. Champman and Hall, London, 434-467

Josylin, M. A. 1970. Acidimetry. Pp. 401-559 in Methods in food analysis (M. A. Josylin, ed.). Academic Press, New York

Kader, A. A. (2005). Controlled atmosphere, Department of Pomology, University of California, Davis, CA, http://una:usda.gov/hb66/013ca.pdf

Kader, A. A., (1992). Postharvest Technology of Horticultural Crops. University of California, Division of Agriculture and Natural Resources, second edition, publication 3311

Kader, A. A. (2002a). Postharvest biology and technology: an overview. In: A A Kader (ed.), Postharvest Technology of Horticultural Crops, University of California, Publication 3311, pp. 39±48

Kader, A.A. (2002). Postharvest technology of horticultural crops. 3rd ed. Univ. Calif. Agr. Nat. Resources, Oakland, Publ. 3311

Kader, A. A., (2003). Summary of CA requirements and recommendations for fruits other than apples and pears. Acta. Horticulture 600, 737-740

Kader, A. A. (1987). Respiration and gas exchange of vegetables. In J. Weichmann (Ed.). Postharvest physiology of vegetables (pp. 25–43). New York, USA: Marcel Dekker

Kader, A. A, Zagory, D., Kerbel, E. L., (1989). Modified Atmosphere Packaging of Fruits and Vegetables. Critical Reviews in Food Science and Nutrition. Vol. 28, Issue 1

Kays, S. (1999). Pre-harvest factors affecting appearance. Post-harvest Biology and Technology, 15:233-247

Kitinoja, L. and Gorny, J.R. (1999). Postharvest technology for small-scale produce marketers:

economic opportunities, quality and food safety. Univ. Calif. Postharvest Hort. Series No. 21

Kupferman, E. and Sanderson, P. (2001). Temperature Management and Modified Atmophere Packaging to Preserve Sweet Cherry Quality., 1–9

Mahajan, P. V. (2002). Studies on controlled atmosphere storage for apple and litchi using liquid nitrogen, PhD thesis, Agricultural and Food Engineering Department, IIT, Kharagpur

Mahajan, P. V and Goswami, T. K. (1999). Controlled atmosphere storage for horticultural crops ± a review paper, Indian Journal of Cryogenics, 22(4), 123±136

Malherbe, S., Sablayrolles, J., & Colombie, S. (2007). Modeling of heat transfer in tanks during wine-making fermentation, 18, 953–960. http://doi.org/10.1016/j.foodcont.2006.05.016

McGuinness, L. E. (2009). How Differing Light Wavelengths Affect the Rate of Fruit Ripening, 2009

Mpelka, C. C. and Kenyon, E. M. (1972). Effect of Light Quality on the Ripening of Detached Tomato Fruit. Food laboratory. Natick Laboratories Natick, Massachusetts (U.S) 01760

Murasawa, N., & Koseki, H. (2015). Investigation of Heat Generation from Biomass Fuels, 5143–5158. http://doi.org/10.3390/en8065143

National Agricultural Institute (NARI), New Guyana Marketing Corporation and the Ministry of Fisheries, Crops and Livestock of Guyana. (2003). Plantain postharvest care and market preparation. Technical Bulleting 2; Postharvets Handling

Nordey, T., Lechaudel, M., Genard M. & Joas, J. (2016). Factors affecting ethylene and carbon dioxide concentrations during ripening: Incidence on final dry matter, total soluble solids content and acidity of mango fruit. J Plant Physiol. 2016 Jun 1;196-197:70-8. doi:

10.1016/j.jplph.2016.03.008

Norgia, W., Mircea, G., Iosif, I. and Camelia, M. (2008). Method for starch content determination from plants by specific weight., *41*(1), 814–818

Nurul N. B. M. S. (2012). Effect of dipping treatment and cassava starch coating on keeping quality of fresh-cut pineapple (Ananas comosus). A Dissertation presented to Faculty of Applied Sciences University Technology MARA. p 1- 15

Odemero, A. F. (2013). Factor Analysis in Small scale Banana Production in the Rain Forest Zone of DeltaS tate, Nigeria. Journal of Natural Sciences Research ,3(1), 1-7

Ofor, M. O., Nwufo, M. I., Ogoke, I. J., Ngwuta, A. A., Ibeawuchi, I. I., & Duruigbo, C. I. (2010). Postharvest Storage Characteristics of Bitter kola (Garcinia kola Heckel .) in Imo State , Nigeria, *3*(3), 6–9

Ogazi, P. O. (1996). Plantain: Production, Processing and Utilization. Paman and Associates Limited, Uku-Okigwe

Okelana, M. A. O. (2001). Chemical Properties and Potential Utilization Of Banana Pseudostem. ASSET Series A (2001) 1 (1): 63-70

Olorunda, A. O. (2000). Recent Advances in Postharvest Technologies of Banana and Plantains in Africa. Acta. Horticulture 534, 517-527

Olusola, L. (2002). Fresh-Cut Fruits and Vegetables: Science. Technology and Market, CRC Press

Parfitt, J., Barthel, M., & Macnaughton, S. (2010). Food waste within food supply chains: quantification and potential for change to 2050. Philosophical Transactions of the Royal Society of London B: Biological Sciences, 365(1554), 3065–3081. JOUR

Park, CY., Kim, YJ. & Shin, Y. (2016). Effects of an Ethylene Absorbent and 1-

Methylcyclopropene on Tomato Quality and Antioxidant Contents during Storage. Hortic. Environ. Biotechnol. 57: 38. doi:10.1007/s13580-016-0130-9

Payasi, A. and Sanwal, G.G. (2005). Biochemistry of fruit ripening. Indian J Agric Biochem. 18 (2). pp.51-60

Peacock, B. C. (1972). Effect of Light on Initiation of Fruit Ripening. *nature new biology* **235**, 62-63. http://krishikosh.egranth.ac.in/handle/1/2054904

Per, H., Kurtoglu, S., Yagmur, F., Gumus, H. and Kumandas, S. (2007). Calcium carbide poisoning via food in childhood. J Emerg Med 32: 179-180

Phillip B., Shittu A. M. , Aiyelaagbe I. O. O and Adedokun T. (2009). Economic Potentials of Plantain and Futed Pumpkin Intercropping as a Poverty Reduction Strategy in South-western Nigeria. World J. Agric. Sci. 5(5):525-534

Pillay, M. A., Tenkouano, A., Ude, G., Ortiz, R. (2004). Molecular characterization of genomes in Musa and its application. Chapter 23. In: SM Jain, R. Swennen, eds. Banana Improvement: Cellular, Molecular Biology and Induced Mutations. Science Publishers Inc., Enfield (NH), USA

Ploetz, R. C., Kepler, A. K., Daniells, J., & Nelson, S. C. (2007). Species Profiles for Pacific Island Agroforestry Banana and plantain — an overview with emphasis on Pacific island cultivars Part 1 : Taxa in the Musaceae, (February)

Prasad, P. and Kochhar, A. (2014). Active packaging in food industry: A review. IOSR J. Environ. Sci. Toxicol. Food Technol., 8(5): 01-07

Radajewska, B. and Borowiak, I. D. (2002). Refractometric and sensory evaluation of strawberry fruits and their shelf life during storage. Acta Hortic., 567: p. 759-762

Rahman, A. U., Chowdhury, F. R and Alan M.B. (2008). Artificial Ripening: What We Are

Eating? J Medicine, 9, 42-44

Ramin, A. A., & Khoshbakhat, D. (2008). Effects of Microperforated Polyethylene Bags and Temperatures on the Storage Quality of Acid Lime Fruits, *3*(4), 590–594

Robinson, J. C. (1996). Banana and plantains. Crop Production Science in Horticulture. (5).CAB International, Wallingford, UK

Rocculi, P. (2006). Use of a simple mathematical model to evaluate dipping and MAP effects on aerobic respiration of minimally processed apples. Journal of Food Engineering, v. 76, n. 3, p. 334-340. http://dx.doi.org/10.1016/j.jfoodeng.2005.05.034

Rodov, V., B. Horev, Y., Vinokur, A., Copel, Y. Aharoni and N. Aharoni. (2002). Modified atmosphere packaging improves keeping quality of Charentais type melon. Hort. Science, 37: 950-953

Rodriguez M. J. L. and S. A. Rodriguez (2001). Socioeconomic aspects of plantain cultivation in Colombia. INFOMUSA. The International Magazine on Banana and Plantain. 10(1): 4-9

Sampaio, S. A., Bora, P. S., Holschuh, H. J. and Silva, S. D. M. (2007). Postharvest respiratory activity and changes in some chemical constituents during maturation of yellow mombin (Spondias mombin) fruit. *Ciência E Tecnologia de Alimentos*, *27*(3), 511–515. http://doi.org/10.1590/S0101-20612007000300014

Sandhu S. S, Singh A. P. (2000). Effect of harvesting dates and individual seal packaging on the pear fruit cv. Le Conte during cold storage. Haryana J Hortic Sci 29:48–52

Shahid, M. N. and N. A. Abbasi. (2011). Effect of bee wax coatings on physiological changes in fruits of sweet orange CV. “blood red”. Sarhad J. Agric. 27 (3): p. 385-394

Sharma, S. S., Sharma, R. R. S., Al, R. K. P., Jhalegar, J. J., Singh, J. S., Srivastav, M. S., & Dhiman, M. R. D. (2012). Ethylene absorbents influence fruit firmness and activity of enzymes involved in fruit softening of Japanese plum (Prunus salicina Lindell) cv . Santa Rosa, *67*(4), 257–266. http://doi.org/10.1051/fruits/2012021

Saltveit, M. E. (2003). Fresh-cut vegetables. In: BARTZ, J. A.; BRECHT, J. K. (Eds.). Postharvest physiology and pathology of vegetables. New York: Marcel Dekker. cap. 22, p. 691-712

Seymour, G. B., Manning, K., Eriksson, E. M., Popovich, A. H and King, G. J. (2002). Genetic identification and genomic organization of factors affecting fruit texture. J Exp Bot, **53**, 463

Silayoi, B., Chomchalow, N. (1995). Cytotaxonomic and morphological studies of Thai bananas. In: GJ Persley, E DeLanghe, eds. Banana and plantain breeding startegies. Proceedings of an International Workshop held at Cairns, Australia 13 - 17 October 1986. ACIAR Proceedings No. 21. Australian Centre for International Agricultural Research, Canberra. pp 157-160

Silva, D. F. P., Salomão, L. C. C., Siqueira, D. L. de, Cecon, P. R., & Rocha, A. (2009). Potassium permanganate effects in postharvest conservation of the papaya cultivar Sunrise Golden. *Pesquisa Agropecuária Brasileira*, *44*(7), 669–675. http://doi.org/10.1590/S0100-204X2009000700003

Simmonds, N. W. and Shepherd, K. (1955). The taxonomy and origins of the cultivated bananas. Journal of the Linnean Society of London (Botany) **55**: 302-312.

Simmonds, N. W. (1966). Bananas. Longman, London, UK

Simmonds, N. W. (1962). The evolution of bananas. Longmans, Green and Co. Ltd, London

Siriboon, N., Basnluslip, P. (2004). A study on the ripening process of 'Namwa' banana. AU J. Technol. 4, 159-164

Sirivatanapa., S. (2006). Packaging and transportation of fruits and vegetables for better marketing. In: Postharvest management of fruit and vegetables in the Asia-Pacifi c Region. Food and Agriculture Organization of the United Nations Agricultural and Food Engineering Technologies Service, Rome

Smith, N. J.; Seymour, G. B.; Jeger, M. J. and Tucker, G. A., (1990). Cell wall changes in bananas and plantains. Tropical fruit in international trade. Acta Horticulturae, 269: 283-289

Sogo-Temi, C.M, Idowu, O.A, Idowu, E. (2014). Effect of Biological and Chemical Ripening Agents on the Nutritional and Metal Composition of Banana (Musa spp). J. Appl. Sci. Environ. Manage. June 2014. Vol. 18 *(2) 243-246.* http://dx.doi.org/10.4314/jasem.v18 i2.14

Sousa-gallagher, M. J., Tank, A. B., Sousa, R. (2016). Emerging Technologies to Extend the Shelf Life and Stability of Fruits and Vegetables. In: The Stability and Shelf Life of Food, pp.399-430 http://doi.org/10.1016/B978-0-08-100435-7.00014-9

Sousa-gallagher, M. J., Mahajan, P. V. (2011). The stability and shelf life of fruit and vegetables. Food and beverage stability and shelf life. Woodhead Publishing Limited. http://doi.org/10.1533/9780857092540.3.641

SPORE (2011). Post-harvest management. Adding value to crops. *T*he magazine for agricultural and rural development in ACP countries.N° 152. http://spore.cta.int

SRID-MOFA, (2014). Ministry of Food and Agriculture, Statistics, Research and Information Department (1992 –2014)

SRID-MOFA, (2010). Statistical, Research and Information Directorate of Ministry of Food and Agriculture. Agriculture in Ghana. Facts and Figures 58 p. http://mofa.gov.gh/site/wpcontent/uploads/2011/10/AGRICULTURE-IN-GHANA-FF-

2010.pdf.

Stuart, T. (2009) Waste, uncovering the global food scandal. London, UK: Penguin

Sugri, I. and Johnson, P. (2009). Effect Of Two Storage Methods On The Keeping And Sensory Qualities Of Four Plantain Varieties, (July). http://doi.org/10.4314/ajfand.v9i4.43880

Sugri I., Norman, J. C., Egyir, I. and Johnson, P. N. T (2010). Preliminary assessment of shea butter waxing on the keeping and sensory qualities of four plantains (Musa aab) Varieties. African Journal of Agricultural Research 5 (19); p. 2676-2684

Suman, S., Kumud, M. and Thakral, S. (2011). Application of apple as ripening agent for banana. Indian Journal of Natural Products and Resources. 3 (1). pp. 61-64

Tchango, J.T., Bikoï, A., Achard, R.,Escalant, J.V., and Ngalani, J.A. (1999). PLANTAIN: Post-harvest Operations. Centre de Recherches Regionales sur Bananiers et Plantains, Cameroon (CRBP). Retrieved from http://www.fao.org/fileadmin/user_upload/inpho/doc s/Post_Harvest_Compendium_Plantain.pdf

The prevension of Food Adulteration Act. (1954) along with the prevension of Food Adulteration Rules. (1955)

Valmayor, R. V., Jamaluddin, S. H., Silayoi, B., Kusumo, S., Danh, L. D., Pascua, O. C., Espino, R. R. C. (2000). Banana cultivar names and synonyms in Southeast Asia. International Network for the improvement of banana and plantain - Asia and the Pacific Office, Languna, Philippines, available online at; http://bananas.bioversityinternational.org/files/files/pdf/publications/synonyms.pdf

Wasim, S. and Dhua, S. (2010). Eating artificially ripened fruits is harmful. Current Science. 99 (12). pp. 1664-1667

Wills, R.; McGlasson, B.; Graham, D. and Joyce, D. (1998). Postharvest: An Introduction to the

Physiology and Handling of Fruit, Vegetables and Ornamentals.4th .Ed. CAB. International, Walling ford Oxen 10 8DE, UK. 262pp

Wong, C., Kiew, R., Argent, G., Set, O., Lee, S. K., Gan, Y. Y. (2002). Assessment of the validity of the sections in *Musa (Musaceae)* using AFLP. Annals of Botany **90**: 231-238

Wu, Z. S., Zhang, M., Wang, S. (2012). Effects of high pressure argon treatments on the quality of fresh-cut apples at cold storage. Food Control, v. 23, n. 1, p. 120-127. http://dx.doi.org/10.1016/j. foodcont.2011.06.021

Yahia, E. M (2006). Modified and controlled atmosphere for tropical fruits, Stewart Postharvest Rev., 5(6), 1±10

Youryon, P., and Supapvanich, S. (2017). Physicochemical quality and antioxidant changes in 'Leb Mue Nang' banana fruit during ripening. Agriculture and Natural Resources, 51(1), 47–52. http://doi.org/10.1016/j.anres.2015.12.004

APPENDIX

QUESTIONNAIRE FOR MARKET SURVEY ON FRESH PRODUCE HANDLING IN SOME SELECTED MARKETS IN THE CITY OF ACCRA

NAME OF RESEARCHER: Nicholas Frank Quarshie

Name of Market…………………………………… Date……………………..

Type of fresh produce………………………………….

Pretest

1. Are you a wholesaler or you buy from the wholesalers for retail? ……………………
2. Where do you receive your supply from?...
3. Do you know how long it takes for the produce to get to you or to the main market center from where it is produced?...
4. How is the produce transported?...
5. Do you encounter any problem during transport? State if yes……………………………

6. Do you package your produce in any form? Yes [ ] No [ ]

7. State the type, if yes……………………………...

8. Do you think the type of packaging used is effective?..

9. Does the produce require holding/storage at the market centre? Yes [ ] No [ ]

10. If yes, how is it done and for how long?...

11. What kind of losses do you incur?...

12. Do you do re-packaging before selling? Yes [ ] No [ ]

13. What do you use for the re-packaging, if yes for 6?...

14. Why do you do the re-packaging?...

15. Does the nature of your produce demand that you delay ripening? Yes [ ] No [ ]

16. If yes, how do you do it?...

17. Are the methods you use to delay ripening effective? Yes [ ] No [ ]

18. For how many days are you able to delay ripening?...

19. Are there times you have to hasten ripening? Yes [ ] No [ ]

20. If yes, how do you do it?...

21. Are the methods of hastening ripening effective? Yes [ ] No [ ]

22. If yes, how quick? State in days or hours………..

23. Do you have any suggestions or comments? State, if yes..
…………………………………………………………………………………………...

Main Survey (On Plantain)

1. Are you a wholesaler or retailer?...

2. From where do you receive your plantain?..

3. Approximately how many days does it take to transport the plantain from the production centre? (Wholesalers/Distributors)…………………………………………………………

4. What is the means of transportation?...

5. Do you package the plantain at any point during handling? Yes [ ] No [ ]
6. State the type and stage, if yes.,…………..

   ………………………………………………………………………………………………..

7. Do you give the plantain any type of special treatment in order to delay ripening, deterioration or bruises during transit? Yes [ ] No [ ]

8. State the type, if yes...……

9. How are the produce offloaded at the destination market? Describe..................................

   ………………………………………………………………………………………………...

10. Do you notice any changes between when the produce arrives on the market and when they are freshly harvested on the field? State the type of change, if yes………………….

    ………………………………………………………………………………………………..

11. Approximately, how many days do you hold the produce at the market centre?................

    ………………………………………………………………………………………………...

12. Do you give the produce any form of treatment to delay ripening/spoilage whiles in storage at the market? Yes [ ] No [ ]

13. State the treatment(s) and duration, if yes..

    …………………………………………………………………………………………

14. Have some of your produce ripened while in storage before? Yes [ ] No [ ]

15. If yes, after how many days do you normally see the ripening?..

16. Have there been times where you had to hasten ripening earlier than normal? Yes [ ]

    No [ ]

17. If yes, how did you achieve it and how quick?...

    ………………………………………………………………………………………..

18. Rank in order which state of the produce fetches high price? (I) Unripe [ ] (II) Half ripe

    [ ] (III) Fully ripe [ ] (IV) Overripe [ ]

19. Which of the following do you think is the major problem in plantain business? Tick one

    i) Distribution/Transport [ ]

    ii) Packaging [ ]

    iii) Storage [ ]

    iv) Financing [ ]

    v) Processing [ ]

    vi) How to delay ripening [ ]

vii) How to hasten ripening [ ]

viii) Others [ ]

20. What's the reason for your choice?..