EFFECT OF CALCIUM CARBIDE AND BIOLOGICAL RIPENING AGENTS ON THE PHYSICAL AND CHEMICAL PROPERTIES OF BANANA

BY

Doris IGUODALA(Miss)

AGR1600330

DEPARTMENT OF CROP SCIENCE
FACULTY OF AGRICULTURE
UNIVERSITY OF BENIN

JANUARY, 2023

EFFECT OF CALCIUM CARBIDE AND BIOLOGICAL RIPENING AGENTS ON THE PHYSICAL AND CHEMICAL PROPERTIES OF BANANA

BY

Doris IGUODALA(Miss)

AGR1600330

A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF CROP SCIENCE, FACULTY OF AGRICULTURE, UNIVERSITY OF BENIN, BENIN CITY. IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF AGRICULTURE (B. Agric) DEGREE (CROP SCIENCE).

JANUARY, 2023

CERTIFICATION

This is to certify that the project was carried out by Doris IGUODALA **(Miss)** with matriculation number **AGR1600330** of the Department of Crop Science, Faculty of Agriculture, University of Benin, Benin City, under the supervision of Prof. T.O EMEDE

_______________________ _______________________
Prof T.O Emede Date
Project supervisor

_______________________ _______________________
Prof. K.E Law-Ogbomo Date
(Head of Department)

DEDICATION

This project is dedicated to God Almighty for his protection, unending love, provision and care throughout my stay in the University of Benin.

ACKNOWLEDGEMENTS

Wholeheartedly, i wish to express my gratitude to the most excellent and omnipotent God for his infinite mercies and protection.

My appreciation goes to my supervisor, Prof. T.O Emede whose guidance and supervision went a long way in contributing to the success of this project work, i say a big thank you sir. I also appreciate the Head of Department Prof K.E Law-Ogbomo for his support, my Course Adviser Prof C.N.C Nwaoguala for his assistance. Moreover, I extend my gratitude to all other lecturers of the Department of Crop Science, Faculty of Agriculture, University of Benin, Prof. A.T. Prof. A.T Adekunle, Prof K.E Law-Ogbomo Prof C.N.C Nwaoguala, Prof A.U. Osaigbovo, Prof. T.O Emede, Prof S.U. Ewansiha, Prof. S.A Ogedegbe, Dr (Mrs) E.J Falodun, Mr Osagie and Mrs M. Omoregie and other staff of the Department.

My profound gratitude goes to my beloved parents, Mr and Mrs Enorense Iguodala for their parental care and love, financial, moral and academic right from birth till date, May God reward you both .Amen

Special thanks goes to my siblings, Mrs Osasere William, Mrs Oduwa Ezewele, Mrs Blessing Evboumwan, Josephine, Faith, Destiny and Raymond for their prayers and love.

And to my friends and course mates Success, Sadiq, Rita, Oke, mama twins to mention a few i sincerely appreciate all the advice and encouragement you gave to me throughout my schooling days. I pray that God grant your heart desires. Amen

TABLE OF CONTENT

CHAPTER FOUR: RESULT

CHAPTER FIVE: DISCUSSION, CONCLUSION AND RECOMMENDATION

LIST OF TABLE

ABSTRACT

Ripening of banana is the major economical concern during the post-harvest which improves the colour, softness, and characteristic aroma of banana and makes them ripened rapidly and palatable as well as more attractive to the consumer. People consume banana fruit ripened with hazardous chemicals like calcium carbide which pose great health risk to the population. Therefore, the present study was carried out to compare the effect of calcium carbide and biological ripening agent on the physical and chemical properties of banana. Treatments included (i) calcium carbide (ii) apple (iii) avocado (iv) oil palm fruits (v) pawpaw), (vi) pear (*Pyrus sp*) (vii) tomato, (viii) control (open air), (ix) control (bag) and (x) unripe banana. Hands of banana containing 10 fingers for each treatment were placed with calcium carbide and the other biological ripening agents in different black polythene bags which was tied up and placed on a table in the laboratory. The experiment was arranged in a completely randomized design in three replications. All sample were monitored for the changes in softness to indicate ripening. Result showed that there was significant differences among the ripening agents in both physical and chemical properties except in pulp percentage. Calcium carbide was earliest in days (5) to 100% ripening but was comparable to most of the biological ripening agent (5.33days). However, calcium carbide ripened banana had pulp to peel ratio of 1.80 while pear (*Pyrus*), apple, avocado and tomato had 1.99, 1.57, 1.53, 1.62 respectively. Calcium carbide ripened banana had the lowest percentage of ash fat and protein compared to biological ripening agents. Also, calcium carbide ripened banana also had the highest level of zinc, copper, manganese and lead compared to biological ripening agents. Thus biological ripening agents like apple, tomato and pear (*Pyrus*) should be adopted as ripening agent to avoid possible health risks from calcium carbide

CHAPTER ONE

INTRODUCTION

Banana (*Musa spp.,* family *Musaceae*) is one of the most traded tropical fruits worldwide, noted as the fourth largest food crop. FAO, (2019) reported that in Africa banana is a very common and popular economic crop, which serves as a major source of income for more than 70 million people around the continent. Bananas are grown majorly for their nutritious and delicious ripe fruits, and its consumption cuts across many segments of the society, including all age groups due to the fact that it is digestible and it supplies the necessary calories and essential micronutrients required (Mesquita *et al*., 2016; Tejas *et al*., 2019). Banana is one of the anti-oxidative foods (Kanazawa and Sakakibara, 2000) and a powerful secondary antioxidant source (Haripyaree *et al*, 2010). It is extremely nutritious (Sharrock and Lustry, 2000) and its consumption rate is high due to its low price.

Banana evolved in the humid tropical regions of Southeast Asia with India as one of its Centre of origin. Modern edible varieties have evolved from the two species- *Musa acuminata* and *Musa balbisiana* and their natural hybrids, originally found in the rainforests of Southeast Asia. During the seventh century AD its cultivation spread to Egypt and Africa. At present banana is being cultivated throughout the warm tropical regions of the world between 30 °N and 30°S of the equator. Worldwide , there is no sharp distinction between ' bananas ' and ' plantains '. Especially in America and

Europe, "banana" usually soft, sweet, particularly those of the Cavendish group, which are the main exports from banana- growing countries. By contrast, *Musa* cultivars firmer, starchier fruit called plantains. In other regions, such as Southeast Asia, more kinds of banana are grown and eaten, so the binary distinction is not useful and is not made in local languages.

The term "banana" is also used as the common name for the plants that produce the fruit. This can extend to other members of the genus *Musa*, such as the scarlet banana(*Musa coccinea*), and the pink banana (*Musa velutina*). It also refers to members of the genus *Ensete*, such as the snow banana (*Ensete glaucum*) and the economically important false banana (*Ensete ventriocum*).

The banana plant referred to as a 'tree, is the largest herbaceous flowering plant. All parts of a banana plant above the ground grow from a fleshy rhizome usually a 'corm' (Stover and Simmonds 1987). The ripe banana is soft and delicate with a post-harvest shelf life of about 5-10 days (Surendranathan *et al*., 2000). It comes in a variety of sizes and colours when ripe, including yellow, purple and red (Englberger, 2003).The chemical composition of banana is water (74.91), carbohydrates (22.84g) and sugar (12.23g).

Banana offer great medical benefits, this is partly because banana aids in the body's retention of calcium, nitrogen and phosphorus, which works to build healthy and regenerated tissues, banana can be used to fight intestinal disorder like ulcers. Banana neutralizes the acidity of gastric juice, thereby reducing ulcer irritation by coating the lining of the stomach.

According to Perotti *et al.*, (2014) and Maduwanthi and Marapana (2019), the ripening process introduces numerous qualities and nutritional characteristics to fruits. The process of fruit ripening is the final stage of fruit development, which is a combination of a series of physiological and biochemical events which leads to changes in pigments, sugar content, acid content, flavour, texture, and aroma that makes the fruit attractive and tasty (Perotti *et al*., 2014).

Fruits can be classified as climacteric and non-climacteric, depending on the ripening pattern. The climacteric stage of fruit ripening is associated with increased production and release of ethylene and an up-regulated cellular respiration. Since banana is a climacteric fruit, it is usually harvested at the preclimacteric stage (mature but unripe) and allowed to ripen (Maduwanthi & Marapana, 2019). Though this practice reduces post-harvest losses of banana especially during transportation; it is often accompanied with induced ripening with artificial agents(ethylene glycol, kerosene , ether, calcium carbide etc.) to meet consumer's demands and economic factors (Abhishek *et al*., 2016). These artificial ripening agents if used inappropriately are toxic and their consumption may cause health problems; such as skin disease, cancer, neurological disorders and organ failure (Krishna *et al*., 2017).

The use of toxic and suspicious ripening agents are of great concern as the activities of human beings have been said to contribute to exposure of food materials to heavy metal contamination (Orisakwe *et al*, 2012). The use of artificial agents may give more acceptable colour than naturally ripened fruits (Hakim *et al*, 2012) but it may increase the risk of contamination of food materials.

Based on the characteristics of artificial ripening agents used in artificial ripening, it can be classified as:

- **Natural ripening**

The ripening process is carried out by means of natural ripening agents and methods (without the aid of chemical substance) For example, placing fruits like apple, avocado etc along with unripe bananas in closed container promote ripening to a greater extent (Mouli and Anton, 2019).

- **Synthetic artificial ripening**

Various chemical compounds are used in greater extent to induce and promote ripening. The ripening method usually involves chemicals either in the form of solid (calcium carbide), liquid (ethereal) and gaseous (ethylene) in nature (Mouli and Anton, 2019).

Calcium carbide (CaC_2) is a chemical compound, considered hazardous due to several reasons, but it is widely used for artificial ripening of banana regardless of the policies surrounding its use in many developing countries (Islam *et al*., 2020). Research had shown that the chemical causes a variety of side effects on human health, ranging from irritation of skin, eyes, chest, and abdomen, vomiting, to burning sensations, seizures and coma even at low concentrations (Nura *et al*., 2018).

The use of toxic and suspicious ripening agents are of great concern as the activities of human beings have been said to contribute to exposure of food materials to heavy metal contamination (Orisakwe *et al*, 2012). The use of artificial agents may give more acceptable colour than naturally ripened fruits (Hakim *et al*, 2012) but it may increase the risk of contamination of food materials.

1.1 Justification

According to Perotti *et al*, (2014) and Maduwanthi and Marapana (2019), the ripening process introduces numerous qualities and nutritional characteristics to fruits. The process of fruit ripening is the final stage of fruit development, which is a combination of a series of physiological and biochemical events leading to changes in pigments, sugar content, acid content, flavour, texture, and aroma that makes the fruit attractive and tasty (Perotti *et al.*, 2014).

Since banana is a climacteric fruit, it is usually harvested at the preclimacteric stage (mature but unripe) and allowed to ripen (Maduwanthi & Marapana, 2019). Though this practice reduces post-harvest losses of banana especially during transportation; it is often accompanied with induced ripening with artificial agents(ethylene glycol, kerosene ,ether, calcium carbide etc.) to meet consumer's demands and economic factors (Abhishek *et al.*,2016). The adverse potential of calcium carbide as a ripening agent has been established (Singal et al, 2012) while other chemical ripening agents like ethepon, etherel and ethylene glycol are also considered hazardous to health and they have to be used within recommended safe limits (Hakim et al 2012; Food and Beverage, 2010). The use of toxic and suspicious ripening agents is of great concern as the activities of human beings have been said to contribute to exposure of food materials to heavy metal contamination (Orisakwe et al, 2012). These artificial ripening agents if used inappropriately are toxic and their consumption may cause health problems; such as skin disease, cancer, neurological disorders and organ failure (Krishna *et al.*, 2017). The use of artificial agents may give more acceptable colour than naturally ripened fruits (Hakim *et al*, 2012) but it may increase the risk of contamination of food materials. With the absence of legislation to control the indiscriminate use of harmful ripening agents, research effort is needed to constantly monitor their presence in foods grown locally.

1.2 Objective of the study

This study was therefore carried out to compare the effects of calcium carbide and biological ripening agents on the physical and chemical properties of banana.

CHAPTER TWO

LITERATURE REVIEW

2.1 Musa systematics

Although there are hundreds of varieties of bananas in cultivation, their taxonomy has been contentious because of their ancient domestication, sterility, hybridization, and the use of diverse common names to refer to the same variety. As most cultivated varieties of bananas are either interspecific hybrids of Musa acuminata and M. balbisiana or hybrids of subspecies of M. acuminata, a genome-based system has led to an overhaul of the nomenclature of domesticated bananas. Unlike most plants, these varieties are identified by their ploidy (number of sets of chromosomes) and parent plant rather than traditional binomial designations. A system of letters("A," B" or "AB") represents the parent plant(s), with a given letter repeated to indicate the ploidy. The popular Cavendish, for example, is referred to as AAA 'Dwarf Cavendish', where AAA signifies its triploid (three sets of chromosomes)as well as its derivation from M. acuminata.

Scientific classification of banana

Kingdom:	Plantae
(Unranked):	Angiosperm
(Unranked):	Monocots
(Unranked):	Commelinids
Order :	Zingiberales
Family :	Musaceae
Genus. :	Musa

Source: Wikipedia

2.2 Origin and Distribution

Bananas are thought to have been first domesticated in southeast Asia, and their consumption is mentioned in early Greek, Latin, and Arab writings; Alexander the Great saw bananas on an expedition in India. Shortly after the discovery of America, bananas were taken from the Canary islands to the New World, where they were first established in Hispaniola and soon spread to other islands and the mainland. Cultivation increased until bananas became a staple foodstuff in many regions, and in the 19the century they began to appear in the markets of the United states. Although Cavendish bananas are by far the most-common variety imported by non tropical countries, plantain varieties account for about 85 percent of all banana cultivation worldwide.

2.3 Utilization of banana

Almost all parts of banana plant are used In different aspects. Whole banana plant is useful in food, feed, pharmaceutical, packaging, and many other industrial applications. The ancient Egyptia ns used banana leaves, fruits, and flowering sheaths, as a wound dressing, often mashing the fruit and applying it as a poultice over rashes, infected scratches, grazes and burns, covered by either the skin or the leaf which was warmed in hot water(Robert, 1999).

Banana flowers; are used as a vegetable in South Asian and Southeast Asia cuisine, either raw or steamed with dipor cooked as soups, curries and fried foods. Both the fleshy part of the bracts and the heart are edible. Banana leaves are large, flexible, and waterproof. They are often used as Ecofriendly disposable food containers or as "plates" in South Asia and several Southeast Asia countries.

Especially in South Indian states of Tamil Nadu, Karnataka, Andhra Pradesh and Kerala in every occasion the food must be served in a banana leaf and as a part of the food a banana is served. Steamed with dishes they impart a subtle sweet flavour. They often serve as a wrapping for grilling food.

2.6.1 Medicinal properties of banana

Banana is not only used as a favourite fruit but also used are all available in plenty.

Presence of iron in banana helps to boost the production of haemoglobin. This helps persons who suffer from anaemia. Banana contains plenty of potassium. This helps to balance sodium potassium level and reduce hypertension or high blood pressure. Banana calms nervous system, reduces stress and depression. Yellow skin banana with dark spots on it is 8 times more effective in enhancing the property of white blood cells than green skin version. As a banana ripens and turns yellow, its level of antioxidants increases. These antioxidants in ripe bananas protect our body against cancer and diseases.

Along with other fruits and vegetables consumption of banana may be associated with a reduced risk of colorectal cancer (Deneo-Pellegrino, *et al*., 1996) and in women, breast cancer (Zhang, 2009) and renal cell carcinoma (Rashidkhani *et al*., 2005).

2.6.2 Traditional Uses of Banana

Banana contain three natural sugars - sucrose, fructose, and glucose combined with fine. A banana gives an instant, sustained and substantial boost of energy. Research has proven that just two banana provide enough energy for a strenuous 90-minute workout. No wonder the banana is the number one fruit with TV world's lead in athletes. But energy isn't the only was a banana can help us keep fit. It can also he'll overcome or prevent a substantial number of illnesses and conditions, making it a must to add to our daily diet.

2.6.3 Industrial Uses

The aforementioned antifungal properties of banana pulp and peel have been successfully used to treat tomato fungus in an agricultural setting. In their home countries, locals use banana leaves for everything from umbrellas to construction materials. Banana and plantain fibres are used throughout the world to weave ropes, mats, and other textiles. Tannins present in ripe banana peel act as tanning agents in leather processing.

2.3 Physical description

The banana plant is a gigantic herb that springs from an underground stem, or rhizome, to form a false trunk 3-6 metres (10-20 feet) high. This trunk is composed of the basal portions of leaf sheaths and is crowned with a rosette of 10 to 20 oblong to elliptic leaves that sometimes attain a length of 3-3.5 metres (10-11.5) and a breadth of 65 cm (26 inches). A large flower spike , carrying numerous yellowish flowers protected by large purple-red bracts, emerges at the top of the false trunk and bends downward to become bunches of 50 to 150 individual fruits, or fingers or bananas, are grouped in clusters, or hands, of 10 to 20. After a plant has fruited, it is cut down to the ground, because each trunk produces only one bunch of fruit. The dead trunk is replaced by others in the form of suckers, or shoots, which arise from the rhizome at roughly six month intervals. The life of a single rhizome thus continues for many years and the weaker suckers that it sends up through the soil are periodically pruned, while the stronger ones are allowed to grow into fruit-producing plants.

2.6.2 Chemical composition of banana fruit

Constituents.	Amount(, mg,g)or percent daily value
Energy	371KJ(89kcal)
Water	74.91g
Carbohydrates	22.84g
Sugars.	12.23g
Dietary fibre.	2.6g
Vitamins	
Pantothenic acid(B5)	0.334mg(7%)
Pyridoxine(B6)	0.4mg(31%)
Choline	9.8mg(2%)
Vitamin C	8.7mg(10%)
Minerals	
Magnesium	27mg(8%)
Phosphorus	22mg(3%)

Potassium	358mg(8%)
Sodium	1mg(0%)
Zinc	0.15mg(2%)

Adopted from:Wikipedia, internet, USDA databases

2.7 Agronomy of banana

Banana plants thrive naturally on deep, loose, well-drained soils in humid tropical climates, and they are grown successfully under irrigation in such semi-arid regions as southern Jamaica. Suckers and divisions of rhizome are used as planting material; the first crop ripens within 10 to 15 months, and thereafter fruit production is more or less continuous. Frequent pruning is required to remove surplus growth and prevent crowding in a banana plantation. Desirable commercial bunches of bananas consist of nine hands or more and weigh 22-65 kg(49-143 pounds).

Three hundred or more such bunches may be produced annually on one acre of land and are harvested before they fully ripen on the plant. For export, the desired degree of maturity attained before harvest depends upon distance from market and type of transportation, and ripening is frequently induced artificially after shipment by exposure to ethylene gas.

Given that each banana variety is propagated clonally, there is very little genetic diversity I. the domesticated plants. This makes bananas especially vulnerable to pests and diseases, as a novel pathogen or pests and diseases, as a novel pathogen or pests and diseases, as a novel pathogen or pest could quickly decimate a variety if it were to exploit a genetic weakness among the clones. Indeed, this very phenomenon occurred in the late 1950s with Bros Michel dessert variety, which had dominated the world's commercial banana business.

2.8 Ripening

Ripening is a biochemical process which involves a series of physiological changes in colour, aroma, flavour, and texture. Banana is a climacteric fruit showing an increase in respiration result in colour, flavour, aroma and texture changes. It is usually eaten raw when ripe and is a major starchy food common in Sub-Sahara Africa and Asia, providing more than 25% of carbohydrate (Adeniji *et al* 2007). The consumption of banana cuts across every age group,from little children to adults, and it supplies necessary calories and essential micronutrients. Once harvested it is highly perishable, with short shelf life leading to high post harvest losses of about 20-50% due to poor handling and quality deterioration (Ajayi and Mbah, 2007;Zewter *et al.*, 2012).

Inorder to reduce the high post harvest losses, bananas are harvested when green but mature, and artificially ripened when needed with the use of ripening agents. Ripening agents are substances which hasten the ripening process, and it comes in different forms. These include ethylene gas, ethepon, ethylene glycol, etherel and calcium carbide (Singal *et al*, 2012); African bush mango fruit (irvingia gabonesis) and leaves, Palm but, Cassia leaves, Yellow pawpaw leaves, torch light battery, calcium carbide, potash and Ash (Ajayi and Mbah, 2007). Africa mango fruits calcium carbide and new bouldia leaves were also reported by Adewole and Duruji (2010).

According to Singal *et al* (2012), the commercial practice to use these ripening agents to artificially ripen the fruits at the destination market before retailing.

2.8.1 Ripening Physiology

The life of a fruit can be divided into three phases: fruit set, fruit development, and fruit ripening. Fruit ripening is the initiation of fruit senescence which is a genetically programmed highly coordinated process of organ transformation from unripe to ripe stage to yield an attractive edible fruit. It is an irreversible phenomenon involving a series of biochemical, physiological, and organoleptic changes. These changes include changes in colour, texture, aroma volatiles, flavour compounds, phenolic compounds, and organic acids.

2.8.2 Biochemical changes during ripening

Fruit ripening is a genetically programmed, highly coordinated process of organ transformation from unripe to ripe stage, to yield an attractive edible fruit with an optimum blend of colour, taste, aroma and texture. A set of biochemical and physical changes occur in banana during ripening which makes it an edible fruit. These changes involves several biochemical pathways like degradation of starch to sugar, change in the peel and pulp colour, cell wall changes, change in the concentration of volatiles and acids.

1. **Tissue softening**

Softening is a very important aspect of the ripening syndrome. Loss of turgor, degradation of starch and enzyme catalyzed changes to wall structure and composition are the mechanisms which leads fruit softening. According to Finney textural change in banana fruit during ripening is predominantly due to the changes in chemical structure of starch grains. Many researchers have shown that starch content in the pulp of Banana decreases drastically during the short period of ripening and then starch is no longer detected. However Kojima suggests that banana pulp softening process is due to the associated process whereby the contents of pectic and hemicellulosic polysaccharides and starch decrease during ripening. According to ALI 50% firmness loss was occurred in 3 days during ripening in Mas banana (Musa acuminata, AA group).

2. Carbohydrates

During ripening process starch is converted in to simple sugars through enzymatic browning process. Starch forms about 20 to 25% of the fresh weight of the pulp of unripe bananas. Sugars are present in the green fruit only about 1 to 2% in the fresh pulp which rises up to 15 to 20% at ripeness. The soluble sugars detected in ripened banana are mainly sucrose, glucose and fructose. According to Adao and Gloria the mean level of starch content in 'Prata' banana was reduced from 15.7 g/100 g to 3.40 g/100 g during ripening. As well total soluble sugar content was increased from 1.26g/100g to 14.3g/100g. Adewale reported that unripe banana (Musa sapientum) had highest amylase activity (3900 ± 310 Units/mg protein) and decreased rapidly to a very low value (100 ±15 Units/mg protein) when it was fully ripened.

3. Pigments

The peel colour changes from green to yellow during ripening of banana fruit. The most important compounds responsible for the change in peel color are chlorophylls and carotenoids. Chlorophyll content decreases become absent in ripe fruit. The level of total carotenoids decreased to half the level at the colour break and subsequently again reached a level similar to that in green fruit. According the major pattern of pulp carotenoids is α - carotene (31%), ß- carotene (28°/o) and lutein (33°/o) of total carotenoids. Banana peel contained 3-4 µg/g carotenoids content as lutein equivalent and ingredients were lutein, ß- carotene, α – carotene, violaxanthin, auroxanthin, neoxanthin, isolutein, ß-cryptoxanthin and α-cryptoxanthin.

4. Pectin

The inter-lamella layer in higher plants composed of polysaccharides mainly pectin. The nature of the pectic component in cell wall is associated with fruit softening. Pectin is a linear chain of α- (1→4)-linked D-galacturonic acid which are methyl esterified. The great strength of green fruit is due to the protopectin or water insoluble pectic which is partially esterified polygalacturonic acid. Increased solubility of pectic polysaccharides is one of the identified changes happens during fruit ripening. Pectic enzymes are related with the softening of fruits along with the increase in soluble pectins. The mainly enzymes involved in pectin degradation are Polygalacturonase (PG) and pectin methylesterase (PME). According to Tapre and Jain, pectin content in banana (Musa sp. var 'Robusta') pulp increased from 0.37-0.66% significantly which was measured as calcium pectate. According to Robinson and Sauco reported ripe pulp in banana contains 0.5-0.7% pectin content. Whereas several studies have been done to characterize pectin degrading enzymes and their activity. Smith and Markovic reported the presence PG in banana tissue. Nagel and Patterson identified that PME activity appears as the fruit ripens and continues to increase exponentially. However Patil and Magar reported that PME activity is highest at colour stage 4 (greenish yellow) and fell down sharply in the advanced stages of ripening.

5. **Organic acids**

Vonloesecke reported the presence of malic, citric, oxalic, and tartaric acids in the banana fruit, with malic acid being the principal acid. Malic and Citric acids are responsible for tartness in the unripe banana while oxalic acid is contributed to astringent taste of the fruit. According to von loesecke titratable acidity of the pulp increases to a peak during ripening in the case of some varieties and then declines.Further it has reported that malic acid concentration has been reported to vary between 0.8 and 7.5 meq/100g and it is increasing three to sevenfold during ripening. The controversial results with Vonloesecke were reported in Soltani where titratable acidity decreased gradually until the fruit reaches to full-ripe (stage-6) then increased at stage-7.

In Malakar and Kulkarni, titratable acidity was decreased during the ripening period. According to Wyman and Palmer malic acid content was 1.36 meq/100g at the pre climacteric stage and it increased up to 5.37 at the climacteric stage and 6.2 meq/100g at the post climacteric stage while oxalic acid content was decreased from 2.33 to 1.37 meq/100g at pre-climacteric stage to post climacteric stage. However total organic acidity was increased during ripening.

6. Astringency

Most fruits and vegetables are astringent in unripe stage and during ripening process astringency is reduced. Similarly banana which tastes astringent in unripe stage becomes palatable in the eating ripe stage. Astringency is claimed to be related to tannins which causes drying, roughing and puckering of the mouth epithelia giving astringency in oral sensation.

Unripe fruit contained considerable level of tannin which reduces as ripening proceeds. However some earlier researches reported that tannin remained unchanged during ripening. The confusion of reduction of astringency and constant value of tannin content was well explained by Barnell and Barnell. According to Von loesecke there are many types of tannin and during ripening solu let tannin becomes insoluble. Barnell and Barnell explained that there are two types of tannin containing elements, latex vessels in both the pulp and peel and small scattered cells in the peel. Further Barnell and Barnell explained that nature of tannin in latex vessels undergo changes while tannin content of the small scattered cells of the skin appears to undergo little or no change.

7. Volatile constituents

Very few researches have been published on aroma compounds and their changes during ripening. The unique aroma of bananas arises from set of volatile constituents including esters, alcohols, ketones, aldehydes and phenol esters. According to Pino and Febles [36]. The composition of banana (Musa spp., AAA group) fruit volatiles included 75 esters, 18 ketones, 14 phenols and derivatives, 7 aldehydes, 13 alcohols, 7 acids, and 12 miscellaneous compounds.

As well isoamyl and isobutyl esters together with 2-pentanone are the major compounds found in banana volatile profile.Mccarthy [38] reported that characteristic banana flavour is due to the amyl esters of acetic, propionic and butyric acids. Jordan studied aromatic profile of fresh banana fruit paste and identified 26 volatile compounds including E-2-hexenal and hexanal as major aldehydes and 3-hydroxy-2-butanone, 3-methyl-1-butanol, 2 pentanol, isoamyl acetate, isomyl isobutyrate, and eugenol were also presented in high concentrations.

CHAPTER THREE

MATERIALS AND METHODS

Bunch of green matured unripe banana (native banana) was bought from new Benin Market, Benin City, Edo state. The ripening agents used was also bought from new Benin Market, Benin city which includes: Calcium carbide, Apple, Avocado (pear), Pear (*Pyrus sp*), Oil palm fruits, tomato and Pawpaw.

3.1 Location of study, treatments, experimental design and layout.

The experiment was conducted from 24th November to 24th December, 2022 at the Main Laboratory of the Faculty of Agriculture, University of Benin, Edo state, Nigeria.

In a clean and conducive environment with room temperature of 29^{o}c, the treatments used included (i) calcium carbide (ii) apple (iii) avocado (iv) oil palm fruits (v) pawpaw, (vi) pear (*Pyrus sp*) (vii) tomato, (viii) control (open air), (ix) control (bag) and (x) unripe banana.

The banana bunch was cut and separated into hands of 10 fingers each with a sharp knife. The hands containing 10 fingers of banana were weighed using a sensitive electronic scale , after weighing the hands of banana were placed into a black polythene bag along with the respective treatments(apple, pear, pawpaw, tomato, palm fruits, avocado) Calcium carbide was wrapped in polythene before it was dropped into the black polythene bag containing the banana. The unripe banana treatment was not place in bag but was used to determine all the physical and chemical parameters evaluated for ripened banana. The bags was tied up and placed on a table in the laboratory. The treatments were arranged in a completely randomized design in three replications.

3.2 Data Collections

All samples were monitored for the changes in softness to indicate ripening. the following data was collected:

3.2.1 Days to 50% ripening

The days to 50% ripening were taken, when 5 out of the 10 fingers used for each treatment have ripened.

3.2.2 Days to 100% ripening

The days to 100 ripening was when all the fingers in each treatment attained ripening.

3.3.3 Temperature in bags.

Temperature of the environment inside the bags for each treatment and the open air temperature for control (open air) were taken daily and average determined.

3.3.4 Pulp to peel ratio

The division of the weight of pulp to the weight of peel results in the pulp to peel ratio.

The ripe banana was peeled using a sharp knife, and then both the pulp and peel were separated and weighed using a digital weighing balance. It was determined by using the formula;

$$\text{pulp to peel ratio} = \frac{weight\ of\ pulp}{weight\ of\ peel}$$

3.3.5 Pulp percentage

The pulp was taken using the weight of pulp all over the weight of pulp and peel which was multiplied by 100

The pulp percentage weight

$$\text{Pulp percentage} = \frac{weight\ of\ pulp}{weight\ of\ peel\ and\ pulp} \text{ x } 100$$

3.3.6 pH in H_2O (ripe/unripe fruit)

The pH of the banana (ripe/unripe) were recorded using this procedure;

- 10g of sample was weighed into a 100ml beaker

- It was mashed and 20ml of distilled water was added.
- It was stirred using a stirring rod for 30mins
- It was allowed rest for 10 minutes
- The pH was read using a standardized pH meter (multipurpose pH meter-model number ORD10)

3.4 Proximate Analysis

3.4.1 Moisture Content

Moisture content is determined by the loss on drying, in which the sample is heated and the weight loss due to evaporation of moisture is recorded. The weight loss due to moisture was obtained by the equation.

$$100 - \% MC = \% DM$$

DM= Dry matter

MC= Moisture content

3.4.2 Ash content

Ash content represents the incombustible component remaining after a sample of the furnace oil is completely burned.

Ash content were determined using a weight of the material (1-5g) is weighed into a previously weighed crucible. The crucible + sample was put into a muffle furnace and the food material ignited at 500^{o}c to 600 ^{o}c in the muffle furnace until the carbon has been removed.

The percentage ash was calculated as followed

$$\% \text{ Ash} = \frac{weight\ of\ ash\ (c-a) x\ 100}{weight\ of\ sample\ (b-a)}$$

Where

Weight of crucible = a gram

Weight of crucible + sample before ashing = b gram

Therefore weight of sample = b-a

Weight of crucible + ash after ashing = c gram

Therefore weight of ash = c-a

3.4.3 Crude fibre

This was determined by subjecting the residue obtained from ether extract to successive treatments of boiling with defined concentration of acid and alkali.

$$\% \text{ Crude fibre} = \frac{weight\ of\ crude\ fibre}{weight\ of\ original\ sample}\ x\ 100$$

Where

W = weight of sample, g

W = weight of original sample, g

W = weight of ash sample, g

3.4.4 Crude protein

Crude protein was obtained from the nitrogen content of the food determined in the sample. The nitrogen content was obtained from all amino acids, amines and nucleic acids present in the sample as reported by Kjedahl method.

The N and crude protein contents can be calculated as follows:

$$\% \text{ crude protein} = \frac{Na \times Va \times 1.4 \times 6.25}{\text{wt of sample}}$$

where:

Na = normality of acid

Va = Volume of acid obtained on titration

1.4= Atomic weight of N

Wt = weight.

3.4.5 Ether extract ("Crude fat)

These were obtained by-continuous extraction of the material with petroleum ether or any other fat solvent such as hexane, pentane, chloroform + methanol or chloroform + ethanol for a defined period.

3.4.6 Nitrogen free extract (NFE)

NFE was obtained by subtracting the amounts of all five fractions above from 100%. Thus NFE was determined as follows:

%NFE=100 - (%'water 4-% crude protein + %crude fibre + % ash +% crude fibre).

3.5 Mineral analysis

The following steps were used to analysed the sample (banana ripe/unripe)

1g of sample was weighed into dry clean crucible

- It was ashed at 600^{o}c temperature for three (3) hours
- It was allowed to cool
- 10ml of 20% HCl was added and warm gently to energise
- It was filtered into 100ml volumetic flask and was made up of 100ml mark
- It was stored in a 100ml plastic reagent bottle for instrumental analysis.

- The sample were read in unicon series atomic absorption spectrophotometer (AAS) ise acetelyne lamps.

3.6 Data Analysis

The data obtained were statistically analyzed using Genstat version 2.1 and the means we're separated using LSD at 5% level of significance.

CHAPTER FOUR

4.0 RESULT

4.1: Effect of calcium carbide and biological ripening agents on the physical properties of banana

The result in Table 4.1 showed that there was significant difference in the days to 50% ripening of banana between calcium carbide and biological ripening agents. Calcium carbide reached 50% ripening faster than the biological agents at 3.33 days. This was not significantly different for apple, pear and tomato (3.33 days). Similarly, oil palm, pawpaw and control (bag) took 4.00 days to 50% ripening. However, control (open air) took the longest days to 50% ripening at 6.00 days and this was significantly different from calcium carbides.

The days to 100% ripening followed similar trend with calcium carbide (5.00) and was significantly different from oil palm, pawpaw and control (bag) which took all taking 6.00 days to 100% ripening while control (open air) was 7.33 days. However, there was no significant difference between apple, pear and tomato (5.33 days) and calcium carbide.

The temperature of the banana was significantly affected by the ripening agents used. Calcium carbide (30.96 ^{o}C) was hotter than apple (30.89 ^{o}C), pear (30.82 ^{o}C) and cooler than avocado (31.44 ^{o}C), oil palm (31.06 ^{o}C) and pawpaw (31.44 ^{o}C) but not significantly different. This was significantly different from control (bag) (31.39 ^oC) and calcium carbide. The pulp percentage was not significantly affected by the ripening agent. Pulp percentage was significantly different for calcium carbide (1.80) and control (open air) (1.19) and unripe (1.05)

Table 4.1: Effect of calcium carbide and biological ripening agents on the physical properties of banana

Treatments	Days to 50% ripening	Days to 100 % ripening	Temperature	Pulp%	Pulp to peel ratio
Ca. carbide	3.00	5.00	30.96	63.96	1.80
Apple	3.33	5.33	30.89	60.92	1.57
Avocado	3.67	5.67	31.17	60.19	1.53
Oil palm	4.00	6.00	31.06	62.27	1.68
Pawpaw	4.00	6.00	31.44	63.57	1.77
Pear (*Pyrus)*	3.33	5.33	30.82	66.45	1.99
Tomato	3.33	5.33	30.96	61.03	1.62
Control (open air)	6.00	7.33	28.60	53.43	1.19
Control (bag)	4.00	6.00	31.39	61.47	1.68
Unripe banana	0.00	0.00	30.00	51.20	1.05
Significance	**	**	**		*
LSD	1.21	0.88	0.81	7.15	0.49

4.2. Effect of Calcium carbide and biological ripening agents on pH and nutritional composition of banana

The result in Table 2 showed the mean values for the properties of unripe and ripe bananas. The protein content of the unripe banana was (3.65%), it was observed that the protein content for ripe banana was (1.50%) for calcium carbide treated banana. The biological agents ripened banana had higher (2.95%) protein contents, than the chemically ripened banana with protein values of (1.50%). Fat content decreased in unripe banana (0.17%) while for the ripe its increases (0.59%). The fibre content increases (3.20%) in unripe banana while its decreases (0.60%) after ripening. Ash content ranged between 1.55-2.81% which was highest in banana ripened with oil palm, but there was no particular trend during ripening as some increased and some reduced. The moisture content of the ripe bananas ranged between (58.50-71.67%). Moisture content in banana pulp was observed to increase because of respiratory breakdown of starch to sugar, migration of water .

Table 2: Effect of Calcium carbide and biological ripening agents on pH and nutritional composition of banana

Treatments	pH	MC%	ASH%	FAT%	FIBRE%	PROTEIN%	CARBOHYDRATE %
Ca. carbide	5.59	71.67	1.55	0.59	1.23	1.50	24.22
Apple	5.05	63.50	2.76	1.23	0.60	2.66	29.28
Avocado	5.50	62.47	2.65	1.41	0.66	2.50	30.18
Oil palm	4.98	58.97	2.81	1.74	1.24	2.41	33.54
Pawpaw	5.51	64.17	2.70	0.67	0.56	2.86	29.07
Pear	5.18	58.50	2.95	1.32	0.62	2.95	33.64
Tomato	4.68	61.03	2.01	0.81	0.97	2.78	32.94
Control (open air)	5.15	66.70	2.68	1.53	1.86	3.33	23.39
Control (bag)	5.57	66.37	2.63	1.55	1.01	3.10	26.01
Unripe banana	5.58	51.90	4.54	0.17	3.20	3.65	37.94
Significance	Ns	**	**	**	**	**	**
LSD	0.64	3.01	0.38	0.11	0.29	0.59	2.89

4.3: Effect of Calcium carbide and biological ripening agents on Heavy metals

The result in Table 3 showed the effect of calcium carbide and biological ripening agents on heavy metals. The highest level was found in calcium carbide treated banana (1.68mg/kg) which was significantly different from all the biological ripening agents. There was significant difference in the Zn level for Apple, Avocado, Pawpaw (0.30mg/kg) and oil palm (0.28mg/kg) and pawpaw (0.38mg/kg). Tomato had the least Zn level (0.10mg.kg) which was significantly different from other agent and both controls.

Similar result was recorded for Cu, Mn and Pb highest level were recorded in calcium carbide (Cu=0.86mg/kg; Mn= 0.63mg/kg and Pb= 0.20mg/kg) and there were significant different from the biological ripening agent and both controls. The lowest level of heavy metal were recorded in tomato (Cu= 0.21mg/kg; Mn= 0.12mg/kg as Pb= 0.01mg/kg).

Table 3: Effect of Calcium carbide and biological ripening agents on Heavy metals

Treatments	Zinc(Zn) ($mgkg^{-1}$)	Copper(Cu) ($mgkg^{-1}$)	Manganese(Mn) ($mgkg^{-1}$)	Lead(Pb) ($mgkg^{-1}$)
Calcium Carbide	1.68	0.86	0.63	0.20
Apple	0.30	0.26	0.18	0.03
Avocado	0.30	0.28	0.17	0.06
Oil palm	0.28	0.25	0.18	0.03
Pawpaw	0.30	0.26	0.15	0.01
Pear	0.32	0.30	0.20	0.03
Tomato	0.10	0.21	0.12	0.01
Control(open air)	0.23	0.22	0.13	0.03
Control(bag)	0.33	0.25	0.15	0.02
Unripe banana	1.00	0.55	0.18	0.04
Significance	**	**	**	**
LSD	0.02	0.02	0.02	0.02

CHAPTER FIVd

5.0 DISCUSSION, CONCLUSION AND RECOMMENDATION

5.1 Discussion

Result showed that there was significant difference in the days to 100% ripening of banana between calcium carbide and biological ripening agents. Calcium carbide reach 100% ripening faster than the biological agents at (5.33days). The temperature of the banana was significantly affected by the ripening agents used. Calcium carbide (30.96 ^{o}C) was hotter than apple (30.89 ^{o}C), pear (30.82 ^{o}C) and cooler than avocado (31.44 ^{o}C), oil palm (31.06 ^{o}C) and pawpaw (31.44 ^{o}C) but not significantly different. This was significantly different from control (bag) (31.39 ^{o}C) and calcium carbide. Calcium carbide can induce ripening within 72hrs and the fact that it is cheap makes it to be a popular ripening agent among banana marketers especially in the developing countries (Ajayi and Mbah, 2007). Gandhi *et al.,* (2016) also compared natural ripening agents including apple, pear, and tomato with calcium carbide. In this study it was revealed that pawpaw is an effective ripening agent compared to calcium carbide and other tested natural agents and it contributed to the highest sensory acceptability.

‘Result also showed the mean of the result of the properties of unripe and ripe bananas. The protein content of the unripe banana was (3.65%), it was observed that the protein content for ripe banana was (1.50%) in calcium carbide. The biological agents had higher (2.95%) protein contents, than the chemically ripened with protein values of (1.50%). Fat content decreased in unripe banana (0.17%) as for the ripe its increases (0.59%). The fibre content increases (3.20%) in unripe banana while its decreases (0.60%) after ripening. Ash content ranged between (1.55-2.81%) which was highest in banana ripened with oil palm, but there was no particular trend during ripening as some increased and some reduced'. 'The moisture content of the ripe bananas ranged between (58.50-71.67%). This is also in agreement with Adewole and Duruji (2010) who observed a reduction in the protein content during ripening which may be due to reduction of nitrogen during ripening. However it does not agree with Sen et al (2012) who stated that proteins increases during ripening'.

The highest level of heavy metals was found in banana ripened with calcium carbide compared to banana ripened with biological ripening agents. There was significant difference in the Zn level for Apple, Avocado, Pawpaw (0.30mg/kg) and oil palm (0.28mg/kg) and Pear (0.32mg /kg). Tomato had the least Zn level (0.10mg.kg) which was significantly different from other agent and both controls. For Cu, Mn and Pb highest level were recorded in calcium carbide (Cu=0.86mg/kg; Mn= 0.63mg/kg and Pb= 0.20mg/kg) and there were significant different from the biological agent and both controls. The lowest level of heavy metal were recorded in tomato (Cu= 0.21mg/kg; Mn= 0.12mg/kg as Pb = 0.01mg/kg). This corroborate the Sogo-Temi *et al.,* (2014), they reported that the chemical ripening agents tested contributed to lower levels of protein compared to biological ripening agents. Also levels of Pb, Cu, Zn, and Mn were higher in calcium carbide treated fruits than other ripening agents. The acceptable limit of Cu for humans is 10ppm, while fruits and vegetables are poor source of Zn, (Ismail *et al* 2011)'.

5.2 Conclusion

'The present study showed that there was significant differences among the ripening agents in both physical and chemical properties except in pulp percentage. Calcium carbide was earliest in days to 100% ripening but was comparable to most of the biological ripening agent. Calcium carbide ripened banana had the lowest percentage of ash fat and protein compared to biological ripening agents. Also, calcium carbide ripened banana had the highest level of zinc, copper, manganese and lead compared to biological ripening agents. Therefore it was necessary to carry out this scientific research to point out the changes that occur in the physical and chemical properties of banana'.

5.3 Recommendation

From the study it's therefore recommended that

i. Further studies should be carried out on the effect of biological ripening agent and calcium carbide on the physical and chemical properties of banana because the nutritional value of banana ripened with biological ripening agent are higher compared to banana ripened with calcium carbide

ii. Marketers should use biological ripening agents for ripening of banana rather than calcium carbide as banana ripened with CaC_2 are higher in heavy metals which are toxic and posed possible health hazards.

REFERENCES

Abdullah, M., Low, G. K., and Matthews, R. W. (1990). Effects of common inorganic anions on rates of photocatalytic oxidation of organic carbon over illuminated titanium dioxide. *Journal of Physical Chemistry*, *94*(17), 6820-6825.

Abhishek, A., and Doherty, M. (2016). Update on calcium pyrophosphate deposition. *Clin Exp Rheumatol*, *34*(4 Suppl 98), 32-38.

Acedo Jr, A. L., and Bautista, O. K. (1991). Commercial-scale application of Gliricidia leaves for enhancing ripening in'Saba'bananas (Musa, BBB group). *Philippine Agriculturist (Philippines)*.

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). *African Journal of Biotechnology*, *9*(54), 9135-9141.

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

Ajayi, A. R., and Mbah, G. O. (2007). Identification of indigenous ripining technologies of banana and plantain fruits among women-marketers in southeastern Nigeria. *Agro-Science*, *6*(2), 60-66.

Beverly, B., Kang, S. M., Lenardo, M. J., and Schwartz, R. H. (1992). Reversal of in vitro T cell clonal anergy by IL-2 stimulation. *International Immunology*, *4*(6), 661-671.

Brandenburg, J. S., and Zagory, D. (2009). Modified and Controlled Atmosphere Packaging Technology and Applications. In *Modified and controlled atmospheres for the storage, transportation, and packaging of horticultural commodities* (pp. 91-110). CRC Press.

Bugaud, C., Daribo, M. O., and Dubois, C. (2007). Climatic conditions affect the texture and colour of Cavendish bananas (Grande Naine cultivar). *Scientia Horticulturae*, *113*(3), 238-243.

Caussiol, L., and Joyce, D. (2001). *Postharvest quality of conventionally and organically grown banana fruit* (Doctoral dissertation, Cranfield University at Silsoe).

Chang, J. S., and Kuo, T. S. (2000). Kinetics of bacterial decolorization of azo dye with Escherichia coli NO3. *Bioresource Technology*, *75*(2), 107-111.

Coe, F. G., and Anderson, G. J. (1999). Ethnobotany of the Sumu (Ulwa) of southeastern Nicaragua and comparisons with Miskitu plant lore. *Economic Botany*, *53*(4), 363-386.

Dá Mesquita, S., Ferreira, A. C., Sousa, J. C., Correia-Neves, M., Sousa, N., and Marques, F. (2016). Insights on the pathophysiology of Alzheimer's disease: The crosstalk between amyloid pathology, neuroinflammation and the peripheral immune system. *Neuroscience and Biobehavioral Reviews*, *68*, 547-562.

Dadzie, B. K., and Orjeda, G. (1998). *Post-harvest characteristics of black Sigatoka resistant banana, cooking banana and plantain hybrids* (Vol. 3). Bioversity International.

Englberger, L., Aalbersberg, W., Ravi, P., Bonnin, E., Marks, G. C., Fitzgerald, M. H., and Elymore, J. (2003). Further analyses on Micronesian banana, taro, breadfruit and other foods for provitamin A carotenoids and minerals. *Journal of Food Composition and Analysis*, *16*(2), 219-236.

Fallik, E and Aharoni, Y. 2004. Postharvest Physiology, Pathology and Handling of Fresh Produce. Lecture Notes. International Research and Development course on Postharvest Biology and Technology. The Volcani Center, Israel. 30pp

Ghani, A., Dexter, M., and Perrott, K. W. (2003). Hot-water extractable carbon in soils: a sensitive measurement for determining impacts of fertilisation, grazing and cultivation. *Soil biology and biochemistry*, *35*(9), 1231-1243.

Hakim, M., Broza, Y. Y., Barash, O., Peled, N., Phillips, M., Amann, A., and Haick, H. (2012). Volatile organic compounds of lung cancer and possible biochemical pathways. *Chemical reviews*, *112*(11), 5949-5966.

Haripyaree, A., Guneshwor, K., and Damayanti, M. (2010). Evaluation of Antioxidant Properties of Phenolics Extracted from Ananas comosus L. *Notulae Scientia Biologicae*, *2*(2), 68-71.

Hofman, G. J., Brack, J. T., Amaudruz, P. A., and Smith, G. R. (1993). Left-right resolution in high magnetic fields for the CHAOS inner drift chamber. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, *325*(3), 384-392.

Irtwange, S. V. (2006). Application of modified atmosphere packaging and related technology in postharvest handling of fresh fruits and vegetables. *Agricultural Engineering International: CIGR Journal*.

Jenny, C., Carreel, F., and Bakry, F. (1997). Revision on banana taxonomy: Klue Tiparot (Musa sp) reclassified as a triploid. *Fruits*, *2*(52), 83-91.

Kader, A. A. (1992). Modified atmosphere during transport and storage. *Postharvest technology of horticultural crops*.

Kanazawa, K., and Sakakibara, H. (2000). High content of dopamine, a strong antioxidant, in cavendish banana. *Journal of agricultural and food chemistry*, *48*(3), 844-848.

Khare, R., Mielke, S. L., Paci, J. T., Zhang, S., Ballarini, R., Schatz, G. C., and Belytschko, T. (2007). Coupled quantum mechanical/molecular mechanical modeling of the fracture of defective carbon nanotubes and graphene sheets. *Physical review B*, *75*(7), 075412.

Krishna, A., Cian, L., and Aydınoğlu, N. Z. (2017). Sensory aspects of package design. *Journal of Retailing*, *93*(1), 43-54.

Maduwanthi, S. D. T., and Marapana, R. A. U. J. (2019). Comparative study on aroma volatiles, organic acids, and sugars of Ambul banana (Musa acuminata, AAB) treated with induced ripening agents. *Journal of Food Quality*, *2019*.

Nakasone, H. Y., and Paull, R. E. (1999). Tropical fruits. Banana. *Wallingford, UK, New York, USACABI Publishing*, 103-131.

Nura, A., Dandago, M. A., and Wali, N. R. (2018). Effects of artificial ripening of banana (Musa spp) using calcium carbide on acceptability and nutritional quality. *Journal of Postharvest Technology*, *6*(2), 14-20.

Orisakwe, O. E., Nduka, J. K., Amadi, C. N., Dike, D. O., and Bede, O. (2012). Heavy metals health risk assessment for population via consumption of food crops and fruits in Owerri, South Eastern, Nigeria. *Chemistry central journal*, *6*(1), 1-7.

Ortiz, R., and Vuylsteke, D. (1994). Inheritance of black sigatoka disease resistance in plantain-banana (Musa spp.) hybrids. *Theoretical and Applied Genetics*, *89*(2), 146-152.

Partha, P., and Hossain, A. E. (2007). Ethnobotanical investigation into the Mandi ethnic community in Bangladesh. *Bangladesh Journal of Plant Taxonomy*, *14*(2), 129-145.

Pesis, E., Beno-Moualem, D., Gusev, L., Dvir, O., Meir, S., and Lichter, A. (2004). The effects of ethylene, methyl jasmonate and 1-MCP on abscission of cherry tomatoes from the bunch and expression of endo-1, 4-β-glucanases. *Plant Science*, *167*(3), 499-507.

Pratt, H. K., and Goeschl, J. D., (1969).*Ann. Rev. Plant Physiol.*, **20**, 541

Reddy, K. R., Hodges, H. F., McKinion, J. M., and Wall, G. W. (1992). Temperature effects on Pima cotton growth and development. *Agronomy journal*, *84*(2), 237-243.

Robert, S. A. (1999). Socioeconomic position and health: the independent contribution of community socioeconomic context. *Annual review of sociology*, 489-516.

Salunkhe, D. K., and Kadam, S. (Eds.). (1995). *Handbook of fruit science and technology: production, composition, storage, and processing*. CRC press.

Seifu, E., Buys, E. M., and Donkin, E. F. (2005). Significance of the lactoperoxidase system in the dairy industry and its potential applications: a review. *Trends in Food Science and Technology*, *16*(4), 137-154.

Sharrock, S. Lustry, C. 2000.Nutritive value of banana,in INIBAP.Annual Report Montpellier, France. 28-31pp

Simmonds, N. W. (1962). The evolution of the bananas. *The Evolution of the Bananas.*

Singal, A. G., Yopp, A., S Skinner, C., Packer, M., Lee, W. M., and Tiro, J. A. (2012). Utilization of hepatocellular carcinoma surveillance among American patients: a systematic review. *Journal of general internal medicine*, *27*(7), 861-867.

Stover, R. H., and Simmonds, N. W. (1987). *Bananas* (No. Ed. 3). Longman Scientific and Technical.

Surendranathan KK, Ramaswamy NK and Pendaharkar MB. 2004. Indian J Biotech 3: 382-
387

Theologis, A., Oeller, P. W., Wong, L. M., Rottmann, W. H., and Gantz, D. M. (1993). Use of a tomato mutant constructed with reverse genetics to study fruit ripening, a complex developmental process. *Developmental genetics*, *14*(4), 282-295.

Zewter, A., Woldetsadik, K., and Workneh, T. S. (2012). Effect of 1-methylcyclopropene, potassium permanganate and packaging on quality of banana. *African Journal of Agricultural Research*, *7*(16), 2425-2437.

Tejas Muthal, Harini R., Sunil C. K. and Chidanand D. V. (2019). Effect of Artificial Ripening Techniques on Physico-Chemical Properties of Banana (Musa sp) Variety 'Poovan' Indian Institute of Food Processing Technology, Pudukkottai Road, Thanjavur, Tamil Nadu – 613005, India. International Journal of Pure and Applied Bioscience 7 (**2**): 482-489

Food and Agricultural Organization (F.A.O), (2019). Banana market review. Rome: Author. Journal of Food, Agriculture & Environment, 10(2): 247–251.

Morton, J. (1987). Date. In. Fruits of warm climates, Julia F Morton, Maimi, FL. Pp 5-11.

Perotti, V. E., Moreno, A. S. and Podest´a, F. E. (2014). "Physiological aspects of fruit ripening: the mitochondrial connection," Mitochondrion, vol. 17, pp. 1–6.

Food and Beverage (2010) . India: Banana ripening is safe .Available from http//www.21food.com. Accessed Jan 29, 2014.

Samson, K. (1991). Effect of chemical nutrients on fruits. *African Journal of Agricultural Research* Vol. 3. (4) pp 246-254 (www.academicjournals.org/AJAR).