38

Addis Ababa University College of Natural Science Center for Food Science and Nutrition

Evaluation of Minerals, Reducing Sugar, Resistant Starch and Polyphenol Oxidase Activities of Selected Banana variety of Ethiopia

BY
REBA BEYENE GURARA

Thesis Submitted to Center for Food Science and Nutrition in partial Fulfillment of the Requirements for the Degree of Master of Food Science and Nutrition

Addis Ababa University College of Natural Science Center for Food Science and Nutrition

Evaluation of Minerals, Reducing Sugar, Resistant Starch and Polyphenol Oxidase Activities of Selected Banana variety of Ethiopia

BY
REBA BEYENE GURARA

Thesis Submitted to Center for Food Science and Nutrition in partial Fulfillment of the Requirements for the Degree of Master of Food Science and Nutrition

Examining Board

W/t HasetTamirat(Chairman)__________

Dr. EmanaGutu(External Examiner) __________

Dr.AshagrieZewdu(Internal Examiner) __________

Mr.KelbessaUrga (Asso. Profesor) Advisor__________

Declaration

I the undersigned, declare that this thesis is my original work and has not been presented for any degree in this or other institution and that all sources of materials used in this thesis have been duly acknowledged.

Candidate Name: Reba Beyene Signature ____________ Date 13/8/06

This thesis has been submitted for examination with my approval as a University advisor. In addition, I declare that this thesis is the original work of my student and has been done under my supervision.

Advisor: KelbessaUrga (Asso. Professor) Signature ____________ Date 12/8/16

Approved by the Examining Board:

Name **Signature**

1. Dr. AshagrieZewdu ____________
2. Dr. EmanaGutu ____________

Place and Date of Submission: Addis Ababa University College of Natural Science
Center for Food Science and Nutrition
Addis Ababa, Ethiopia

June, 2016

Table of Contents Page

Acknowledgements--i

List of Tables---ii

List of Figures--iii

List of Acronyms---iv

Abstract--vi

1. Introduction--1

1.1. Background of the Study---2

1.2. Statement of the Problem---4

1.3. Significance of the Study--6

2. Objective--7

2.1. General Objective---7

2.2. Specific Objective--7

3. Literature Review---8

3.1. Center of Origen of Banana--9

3.2. Taxonomy and Genetics of Banana---10

3.3. Ethiopian Banana Varieties --11

3.4.Cultivar giant cavendish--16

3.5 Cultivarbutuza---17

3.6 Cultivarrobusta--18

3.7 Cultivar williams---19

3.8 Cultivarpoyo--20

4. Nutrient Composition of Banana--21

4.1. Mineral Profile---23

4.1.1. Zinc--25

4.1.2. Iron---26

4.1.3. Potassium---27

4.2. Reducing Sugar---28

4.3. Resistant Starch--29

5. Polyphenol oxidase activity--30

6. Materials and Methods--33

6.1 Location of the study---34

6.2 Chemicals---34

6.3 Sample Collection----------34
7. Analytical Methods----------34
7.1. Determinations of Moisture ----------34
7.2. Determination of Ash----------35
7.3. Determination of Mineral----------36
7.4. Determination of Reducing Sugar----------38
7.5. Determination of Resistant Starch----------38
7.6. Determination of Polyphenol Activity----------38
7.7. Experimental Design----------39
8. Result and Discussion----------40
8.1 Moisture and Ash----------40
8.2 Mineral Contents----------41
8.3 Reducing Sugar Contents----------42
8.4 Resistant Starch Contents----------43
8.5 Polyphenol oxidase Activity----------44
9.Conclusion----------46
10. Recommendation----------47
11. References----------49

ACKNOWLEDGEMENT

First and foremost, I would like to thank the Almighty God who gave me a gift of life till this day, giving me strength, help me to do this work and guidance throughout my life. It is with great pleasure and gratitude that I acknowledge my advisor KelbesaUrga (Ass. Professor) for his consistent and simulating advice, invaluable inputs, and critical reading of my draft thesis and continuous interest throughout the research period. I wish to extend my sincere heart full appreciation and respect to my MenageshaAmba Maryam and GarawMedhanealem union monasteries and D/T/S/George Sunday school for supporting me during printing this thesis. I am grateful to Melkasa Agricultural Reserarch Institute horticulture center workers for their unreserved free support at giving samples of banana. The last and foremost I would also like to acknowledge my mother for her un restricted support for all of my life and until the end of my education.

LIST OF TABLE

Page

Table One: The nutritional values of bananas per 100g of edible fresh portion-------------------------------26

Table Two: Vitamin content of the banana per 100g ripe, edible banana--------------------------------------26

Table Three: Mineral content of the banana per 100g ripe, edible banana-------------------------------------28

Table 4. Moisture in fresh basis and Ash in dry basis (g/100g) of row Banana--------------------------------48

Table 5. Mineral content (K, Fe, and Zn) of banana fruits (mg/100 g dry weight) ---------------------------49

Table:6 Reducing Sugar Content (%) of Banana Varieties--51

Table 7. Total starch, digestible starch and RS (g/100g dry weight) of different banana cultivars----------52

List of Figures

Page

Figure 1 Cultivar Giant Cavednish--20

Figure 2 Caltivar Butuza---21

Figure 3 Caltivar Robusta--22

Figure 4 Cultivar Williams---23

Figure 5 Cultivar Poyo--24

Figure 7 Polyphenol oxidase activity of selected banana varieties at dry mater------------------------------53

List of Acronyms

AAS	Atomic absorption spectrometry
AGDHA	Australian Government Department of Health and Aging
AOAC	Association of Official Analytical Chemists
ANOVA	Analysis of variance
AR	All terms
BBMV	Banana Bract Mosaic Viral
BSV	Banana Streak Virus
BTH	Butylated Hydroxyl-Toluene
BBTV	Banana Bunchy Top Virus
CGIAR	Consultative group on international agricultural research
CH3OH	Methanol
CH2Cl2	Ethyl Chloride
CSA	Central statistics Agencies
C6H14	Hexane
FAO	Food and agriculture organization
GHI	Global hunger index
HCl	Hydrochloric acid
HCHO	Formaldehyde

HG-AAS	Hydride generation atomic absorption spectrometry
HIV	Human immune deficiency virus
HPLC	High performance liquid chromatography
IDA	Iron deficiency anaemia
KOH	Potassium hydroxide
LSD	Least significance difference
OFSP	Orange fleshed sweet potato
PPO	polyphenol oxidase
RBP	Retinol binding protein
RS	Resistant starch
THF	Tetrahydrofuran
UK	United Kingdom
UNHCR	United Nations health and children
UNCST	Uganda National Council for Science and Technology
UV	Ultra violet rays
VAD	vitamin A deficiency
WFP	World food program
WHO	World Health Organization

Abstract

Banana cultivation is considered one of the most important agricultural activities of economic and social importance in Ethiopia. The objective of this work was to investigate minerals, reducing sugar, resistant starch and polyphenol oxidase activities of fiveselected banana varieties, these are giant cavendish,butuza,robusta,poyo and williamsofEthiopia. Banana fruits were collected, dried, ground and ashed. The mineral elements potassium(K), Iron (Fe) and zinc(Zn) were analyzed. Their composition was found to be 0.627 - 1.047 mg/100g for iron, 0.217 - 0.307 mg/100g for zinc and 287.171 - 355.271 mg/100g for potassium inripe banana fruits. Bananas are considered a good source of K in the diet, and the data obtained herein support these assertions. Zn and Fe are other minerals of nutritional importance in bananas and this study has shown that their average values are adequate to support its nutritive value at ripening stages.The RS content of banana were between 52.2 - 61.4 g/100g that containing the highest amount of RS, banana has a higher RS content the highest value comingfrompoyo followed by Giant Cavendish.For reducing sugar, the sample extract was filtered through the two layers of cloths and re-extracted in hot 80% alcohols, using 2 to 3 ml of alcohol per gm of sample and tested by Fehling's solution. The precipitate and color change of the sample were calculated by titration method and Polyphenol oxidase has been shown to be responsible for browning reactions and discoloration in banana fruit. Polyphenol oxidase was indirectly isolated. The activity of the enzyme was evaluated using Hallberg and Halthen's algorithm method. Banana PPO catalyzes oxidation of both various substrates with catechol being the most readily oxidized substrate. The optimum pH of the enzyme was between pH 6 and 7 for all cultivars. Banana polyphenol oxidase was active towards catechol but not withgalloyl.The result obtained in this study showed that banana fruits can be a potential source of mineral elements supplement in the diet especially for k, and good source of resistant starch and reducing sugar.

Key words: Banana, mineral,reducing sugar, resistant starch and polyphenol oxidase

Chapter 1 - *Introduction*

1. Introduction

1.1 Background of the study

Banana (Musa species) a term including plantain, grows widely throughout the humid tropics and is a common staple food for many people in developing countries, as well as a popular fruit worldwide (Randy et.al.2007). Musa species comprising dessert bananas and plantains, are among the world's leading fruit crops as source of energy in the diet of people living in humid tropical regions. Over hundred million people are estimated to depend on banana fruit for a large proportion of their daily carbohydrate intake (Mmeka et. al., 2013).

Bananas are multipurpose plants, because most of their parts can be used in various ways, depending on the species. The most important part is the edible fruit, which can be eaten either ripe as a dessert or unripe as boiled, fried or roasted food (Smith et al. 2005). Nutritionally, the fruit is rich in carbohydrates, vitamins A, B, and C, and potassium (Aurore et al., 2009). The unripe fruit can be brewed to form beer and wine, or processed into sauce, flour, chips, crisps, smoked products, and sweet. Unripe fruit is also a source of amylase and starch (van den Houwe et. al., 2000). Male floral buds can be eaten as a boiled vegetable, whereas pseudostems are a source of fiber for the manufacture of rope, paper, and textiles. Banana leaves are used for the production of fabric and cordage, and as much and animal forage (Smith et al. 2005).

Plantains are larger, more angular starchy fruits of hybrid triploid cultivars in the banana family intended for cooking (Robinson, 1996). Except in India and Southeast Asia, where dessert bananas are consumed in large quantities, the use of cooked bananas and plantains is not so widespread (FAO, 2014). The methods used to cook bananas and plantains do not generally involve elaborate processes, being prepared by boiling or steaming, baking or roasting and frying. However, in some areas, particularly West Africa, the fruit is also powdered. Roasted or baked bananas and plantains are also prepared in both East and West Africa by placing peeled or unpeeled fruit either on the ashes of a fire or in an oven (Walker, 1931; Dalziel, 1937; Boscom,).

Bananas and plantains constitute one of the major staple foods as well as providing a valuable source of income through local and international trade for millions of people and estimated to meet more than a quarter of the food energy requirements in the African continent (Coulibaly et. al., 2007). It is estimated that about 70 million people in west and central Africa derive more than a quarter of their food energy requirement from plantain (Singh et al., 2011). FAO considers banana as the fourth most important food in the world, after rice, wheat, and maize and represents the world's second largest fruit crop with an annual production of 129,906,098 metric tons (Priver, 2011). At present, banana is grown in around 150 countries across the world on an area of 4.84 million hectares producing 95.6 million tons (FAO STAT, 2011). It is grown widely in all types of agricultural systems, ranging from small, mixed subsistence gardens to large, multinational commercial plantations.

Banana, including a number of hybrids in the genus Musa, dessert bananas and plantains. The dessert bananas have firm pulp when the fruit is not ripe and soft pulp during its maturation (Kajuna et al., 1997). It is known that dessert banana pulp and peel contains some secondary metabolites in their composition, e.g. catechol amines (Kanazawaand Sakakibara, 2000), phenolics (Verde-Mendez et al., 2003), and carotenoid compounds (Van den Berg et. al., 2000), as well as pyridoxine (vitamin B6- Leklem, 1999). Many of banana's volatile compounds such as esters (Pérez et al., 1997) and alcohols (Nogueira et al., 2003) play an important role in the aromatic properties of dessert bananas. As in dessert bananas, the pulp and peel of diverse plantain cultivars also have phenolic compounds (Tsamo et al., 2015). There are many varieties of banana, mostly based on *Mussa acuminate* colla (designated as A) and *Mussa balbisiana* colla (designated as B), with a wide diversity of diploidic, triploidic, and tetraploidic hybrid varieties having widely differing properties and composition (Nweze et. al., 2015).

Concerning the introduction of banana to Ethiopia, it is not Known when it entered to the country but banana has been cultivated for several years in Ethiopia as a garden plant. In Ethiopia, the major banana producing regions are Southern nations, nationalities and peoples, Oromia and Amhara regions (Atsbaha et. al., 2012). During the 2010/2011 production season about 31, 885.86 hectares of land has been covered with banana and the estimated annual production was about 270571.516 tones (Tsegaye et. al., 2012). The actual yields are less than 40 t/ha/year whereas, the potential yield of banana is greater than 70 t /ha/ 1year (Tekle et. al., 2014). The poor productivity of banana has been attributed to a number of biophysical factors. In Ethiopia, banana is the second major fruit crop next to citrus. The cooking and table bananas are adapted to relatively high altitude and humid regions, whereas matoke (AAB) and cardaba (ABB) types are produced in more arid regions due to their resistance to drought. All sorts of varieties (dessert, cooking, brewing) are grown in Ethiopia. Even if banana is a staple food and good source of income for a number of Ethiopian farmers especially in south and south west region (Atsebeha et. al., 2012), the varieties are not well studied (Seifu Gebre-mariam, 1999).

Over the years a number of problems faced the production of this crop in Ethiopia. Of these, lack of improved varieties was the critical problem to banana and all varieties are equally cultivated and selected by farmers or they depend only on the quantities not quality of the plant (Teshome, 2013). There are not enough public or private banana companies producing banana planting materials. Growers obtain their banana planting material from their orchards or from neighboring orchards. Therefore, rapid propagation is needed to distribute the plants to growers. The optimization of multiplication and rooting of these new types will aid banana cultivation not only in Ethiopia but also in other tropical and subtropical regions. It is the most important cash crop in some parts of southern Ethiopia, especially Gamo Gofa zone and South Omo Zone (Teshome, 2013).

1.2 Statement of the problem

Food insecurity especially in developing countries is getting worse with an estimated one hundred million people set to join the ranks of the world's hungry annually (Tesfaye, 2013). The number of hungry people is expected to rise to more than one billion worldwide or 16% of the world population as a result of food price increases (Teshome et. al., 2013). The global hunger index (GHI) shows that the world progress in reducing hunger is slow, remaining distressingly high in sub-Saharan Africa (Kahsay et. al., 2012).

Ethiopia hosts more than 18.5 million people who are face challenges of food insecurity. One of the main causes of food insecurity in east Africa is poverty. Households in the country are characterized by high incidents of malnutrition largely driven by poverty. There are environmental traps in which some households and areas appear caught in a vicious cycle of low income, low investment in soil management, declines in the soil fertility and the soil loss. It is therefore suggestive that food insecurity and the malnutrition that are common in Ethiopia be addressed through indigenous mechanism such as promotion of fruits like banana. Such crops are rich in nutrients.

Nowadays the strategy to reduce poverty, researchers focus on some selected fruits and vegetables. The use of fresh fruit in addition to supplementation are recommended to reduce nutrient deficiency specially vitamins and minerals (UNHCR/WFP, 1997). But the micronutrients level in fruits such as banana are not stable (Weise and Benoist, 2002) and decrease on storage, because of high activity of polyphenol oxidase. Findings in banana growing regions indicate that levels of zinc are low in banana based weaning foods and zinc intake in the general population is sub optimal. Several studies suggest improving zinc nutrition should be made a priority, especially in regions where zinc is predominately lacking in their staple plant based diets. Although the majority of banana varieties are relatively rich in carbohydrate, resistant starch, they have low amounts of iron, zinc but high in potassium. The majority of children that are weaned primarily on cooking bananas in Uganda are exposed to diseases associated with iron and zinc deficiencies. Zinc is important for the immune system, and iron is important for brain development in utero. By promoting consumption of bananas with enriched micronutrients, severe deficiencies can be reduced in developing countries where diets are largely banana based. Furthermore, increasing the nutritional value of bananas through breeding will enhance the health and well-being of the people.

Studies on nutrient composition of bananas varieties in Ethiopia is not well documented, and as a result there is no comprehensive documentation of micronutrient composition of bananas in the country. The aim of this study is to determine the variation in potassium, iron and zinc, reducing sugar, resistant starch and polyphenol oxidase activities between acceptable cultivated bananas varieties in Ethiopia.

1.3 Significance of the study

The results of this study provide background information against the improvements in consumption or utilization of the banana. It also provides diversified uses of different banana varieties with different nutritional value from different locations of the country. This study also provides a data bank of minerals, reducing sugar and resistant starch of different selected varieties of banana and can guide nutritionists and breeders in search of better breeds that can qualitatively and quantitatively be useful in addressing food security and permit to prevent malnutrition. Since Ethiopia can claim of a potential market of over ninety-four million people within the East African community, popularization and marketing of processed and raw varieties will economically empower and improve the livelihoods of the people of the country by addressing the poverty levels and malnourishment disorders.

2. Objective

2.1 General Objective

To analyze reducing sugar, zinc, iron, potassium and resistant starch contents and polyphenol oxidase activities of selected banana varieties of Ethiopia.

2.2 Specific Objective

-To screen banana cultivars for Zinc, Iron, Potassium reducing sugar and resistant starch commonly available for commercial in Ethiopia.

-To identify further banana cultivars that may be promoted to improve mineral deficiency and resistant to browning.

-To obtain information about the polyphenol oxidase activity of the selected banana varieties.

Chapter 2 – *Literature Review*

3. Literature review

3.1 Center of origin of banana

The origin of edible banana is not known, but generally accepted theory is that Malaysia and biogeographical region including the Malay Peninsula, Indonesia, Philippines and New Guinea was the primary centers and India was the secondary center (Langhe,2009). It is thought that traders from Arabia, Persia, India and Indonesia distributed banana suckers around coastal regions of Indian Ocean between the 5th and 15th centuries (Hakkinen et. al.,). From the 16th to 19th centuries, suckers were traded by Portuguese and Spanish in tropical America. Further, world trade saw the establishment of bananas in Latin America and Caribbean (UNESCO, 2003). Today the cultivation of banana occurs throughout the tropics and subtropics of Asia, America, Africa and Australia.

Although the East African plateau is considered a secondary center of diversity of bananas particularly the Lujugira-Mutika subgroup. The region is not a major player in the global market, and the export potential of these bananas has not been exploited as an alternative source of income for the small scale farmers (Gubbuk et. al,.2004). The region however, is rich in its banana diversity with over 100 cultivars savored and exploited. Farmers in East Africa describe these cultivars by names related to one or more traits at various development stages of the plant life cycle, like agronomic performance, uses of plant parts or aesthetics (Nelson et. al., 2006). East Africa and West Africa represent two main secondary centers of musa diversity as a result of long history of cultivation in these regions. Approximately 60 cultivars of African highland bananas are unique to East Africa, but is not known whether these derived plants or from indigenous edible diploids. These highland bananas have the AAA genotype. It is through these plantains reached West Africa 3000 years ago and that they may have initially been propagated for their starch and/or fibers rather than for their fruit. Vegetative propagation eventually led to the evolution of fleshy seedless fruits that were edible. Another secondary center of diversity is Polynesia were the Maia Maoli/ Popoulu cultivars (through AAB hybrids) were carried from the Philippines more than 4000 years ago.

Edible diploids of *Mussa balbisiana* underwent a parallel evolution in drier parts of Asia (India, Myanmar, Thailand and Philippines) but there was some geographical overlap with *Mussa acuminate* and hybrids of the seeded types were produced (Kumar et. al., 2008). The Indian subcontinent was a major center for hybridization. The genomes of the two species contributed different traits with *Mussa acuminata* largely contributing parthenocarpy and sterility and *Mussa balbisiana* contributing hardiness, drought tolerance, disease resistance and starchiness (Poetz et. al., 2014). Most of the cultivars of the edible bananas derive from collections of spontaneous mutants in wild plants that were then brought into cultivation multiplied and vegetatively.

3.2 Taxonomy and genetics of banana

Musa taxonomy is confused by several factors including the sterility, ancient domestication, and hybrid origins of the cultivated varieties (cultivars), and the unwillingness of many to adopt newer, correct names (Randy et.al., 2007). For example, Linnaean binomials such as *Mussa paradisiaca* ('French' plantain) and *Mussa sapientum* ('Silk') are still used decades after the cultivars to which these names refer were recognized as *Mussa acuminata* × *Mussa balbisiana* hybrids. Most edible bananas originated from two species *Mussa acuminata and Mussa balbisiana* (Boshra et. al., 2013). The cultivars are either hybrids among subspecies of *Mussa acuminata* or between *Mussa acuminata* and *Mussa balbisiana*. These hybrids are diploid (two sets of chromosomes), triploid (three sets, the most common and important ploidy), or tetraploid (four sets). A perceptive observer can usually deduce a variety's genome (i.e., its ploidy and relative content from *Mussa acumniata* and *Mussa balbisiana*) by observing leaf thickness, size, and orientation, and by using a scoring system that considers 15 morphological characteristics (Salawu et. al., 2015). However, ploidy is best determined by chromosome counts or flow cytometry. These include pseudostem ("trunk") color, leaf stem (petiole) structure, fruit stalk (peduncle) hairiness, shape and size of the male bud, scars left from falling flowers on the lower fruit stalk (rachis), and details of the male flowers (Bayu et. al., 2015). When denoting each cultivar's genome, a lettering system is used. For example, *Mussa acuminata* and *Mussa balbisiana* are diploids, with genome AA and BB, respectively, and AA and AB clones are cultivated. Hybrid triploids are classified as AAA, AAB, or ABB (Meka et. al., 2013). Tetraploid bananas (mostly products of breeding programs) may be AAAA, AAAB, AABB, or ABBB. *Mussa acuminata* evolved primarily in tropical rainforests in Southeast Asia, whereas *Mussa balbisiana* originated in monsoon areas in northern Southeast Asia, and Southern Asia. Thus, pure *Mussa acuminata* cultivars developed first in Southeast Asia and its hybrids with *Mussa balbisiana* arose where distributions of the two species overlapped (Abebe, 2013). As newly discovered hybrids were carried by indigenous peoples by land and sea, more opportunities for hybridization arose, especially since not all were completely sterile. However, variation in the crop in its secondary centers resulted primarily from mutations in the cultivars (Tekle et. al., 2014). Major secondary centers of diversity occur in West Africa (Plantain subgroup), Polynesia (Maoli-Popoulu and Iholena subgroups, aka Pacific Plantains), and East Africa (Mutika/Lujugira subgroup, aka East African Highland Bananas).

Historically, four sections have been recognized in musa those are Australim musa, Callim musa, Musa (formerly known as emusa), and Rhodochlamys. Recent molecular analyses indicate a reduction to two sections, but much further study is required before the above system is abandoned. Section Australimusa (chromosome number: x = 10) Seeds sub globose or compressed, smooth, striate, tuberculate or irregularly angled, Contains the Fe'i bananas, which are important in the Pacific

(UNCST, 2007). Their origins are complex and may involve as many as three species, *Mussa lolodensis, Mussa maclayi* and *Mussa peekelii.* Also included in the section is an important source of fiber, abacá (*Mussa textilis*). Section Callimusa (chromosome number: x =10) Bracts plain, firm, shiny on the outer surface, rarely glaucous and strongly imbricate when closed (Dagan, 1989). These plants are most important as ornamentals. Most bear upright flower stalks, variously colored buds and flowers, and small seedy fruits. Section rhodochlamys (chromosome number: x = 11) Many highly ornamental species are found in this section. Section Musa (former section) Eumusa (chromosome number: x = 11) Most cultivated varieties (cultivars) of edible banana originated from two species in this section, *Mussa acuminata* and *Mussa balbisiana* (Gnansounou et. al., 2014).

The modern day banana is a mix of wild and cultivated species and hybrids associated with *Mussa acuminata* and *Mussa balbisiana. Mussa acuminata* is the most widespread of the species (Adeyemi et. al., 2009). Some of the primitive edible seeded diploids of this genus evolved through the development of sterility parthenocarpy and fleshy seedless fruits. The genetic basis of parthenocarpy in *Mussa acuminata* has not be characterized. Clones of the diploids were cultivated in wetter parts of southwest Asia and the development of vigorous seedless triploid cultivars was the result of chromosomes restitution and/or crosses between edible diploides and wild M. acuminate (Shumaila et. al., 2009).

3.3 Ethiopian banana varieties and production

Ethiopia has a diverse agro-ecology and sufficient geographical area of 1.13 million km^2 and a total human population of over 84 million (CSA, 2007), is agro-ecologically diverse and can support production of temperate, sub-tropical and tropical fruits (Atsbaha et. al., 2009). It has areas with altitudes ranging from 116 m below to 4620 m above sea level. Twelve major river basins in Ethiopia have an annual flow of 123 000 million m3 of water with a ground water potential of about 2.56 million m3. This gives the country a potential irrigable area of 3.5 million ha with net irrigation area of about 1.61 million ha, of which currently only 4.6 % is utilized (Amer, 2002). Those resources are suitable for growing various temperate and tropical fruits. Although various tropical and temperate fruits are grown in the lowland/midland and highland agro-ecologies. Despite this potential, the area under fruit crops in Ethiopia is very limited. About 450,932 ha of land was estimated to be under vegetable, root and fruit crops in 2004, of which about 40,600 ha (9%) is mainly under smallholder fruit crop production. Total fruit production in Ethiopia was estimated at about 320,000 tonnes (FAO, 2002).

Banana has several economic values for Ethiopian banana producers, as human food and animal feed (Seifu et. al., 2003). Production is concentrated in the southern region of Ethiopia and the major products comes from small scale growers.

The average banana production in between 1961 and 2009 production year varied from 60,000 t in 1961 to 240,000 t in 2009. Its production and utilization has many technical, economic and social problems that attract research attention in order to exploit its immense suitability potential (Almaz,1990). The Ethiopian Institute of Agricultural Research (EIAR) introduced some banana germplasms and the collection of local cooking banana clones. Eleven varieties including four cooking type banana varieties were released in 2006 by Melkassa Agricultural Research Centre based on their better agronomic performance as well as increased disease resistance. Production and processing of banana in Ethiopia could play a great role in ensuring adequate food supplies to the teeming population, diversification, addressing micronutrient deficiencies in populations, produce raw materials for domestic industries and create employment opportunities (Awol, et. al., 2011). The trend in other countries indicated that the introduction and promotion of banana processing could be an interesting alternative for countries, which have agroindustry development as a key component to underpin the government's agricultural diversification program that exists as primary producer with very poorly developed agroindustry (Davies 1995; Abdul-Rasaq and Lateef 2011).

Expansion of food industry in the urban areas and the increase in demand for processed foods especially for children, is expected to create demand for banana processing into different final products. Generally, to change the retarded state of development of agro-industry in Ethiopia, as it is being observed on potato chips in different parts of the country, cooking banana chips processing could also play an important role (Seifu, et. al., 2003). The processing industry can promote cottage agro-industry for rapidly expanding tourism and provide income generation opportunities for low income group entrepreneurs. Moreover, processing is recognized as a way of preserving fruit. As banana fruit has a limited shelf life, processing is important (Workineh, et. al., 2011).

The production and utilization of banana have been consistently increasing since 2006 in Ethiopia. Yet the proportion of fruit processed and the suitability of the various varieties to processing is relatively not well known (Tigist, et. al., 2011). The existing potential could only benefit the nation if it could be fully exploited through the export of processed banana products, including chips. As was mentioned earlier, all improvement works conducted in Ethiopia, particularly, on banana, focused mainly on selecting promising varieties in terms of high yield, cold tolerance, disease and insect resistance without giving much attention to post harvest and processing quality evaluation (Seifu, 2003). Moreover, the improvement efforts would be complete and sustainable, if the breeder materials could be tested for their processing quality in different value added food products such as chips and dried products (Seifu, 2003; Chavan et. al. 2010). Adeniji et. al. (2010) reported that cooking bananas including plantains are used to combat food insecurity in Sub-Saharan Africa. It is estimated that more than 30 % of the banana production are lost after harvest (Adeniji et. al. 2010). The losses are mostly due to fast deterioration resulting from the rapid ripening as well as lack of postharvest technologies to be used during storage and transportation. Processing cooking banana and plantain to shelf stable end products can provide appropriate solutions and help to exploit different marketing options. However, very limited scientific information exists on processing of cooking banana including plantains (Workineh, et. al.,2011).

Banana export from Ethiopia started at less than 5,000 tonnes in 1961 but jumped to 60,000 tonnes in 1972 and was exported to many countries in Europe, Asia and Africa (Taye, 1975). In 2003, Ethiopia exported only about 5,366 tonnes of various fruits (including banana), and earned only about Birr2 13.3 million. Of this only about 1,300 tonnes worth Birr 2.8 million was from banana exported mainly to Djibouti (CSA, 2004). Global share of Ethiopia in banana export was only about 0.01% (FAO, 2003). The limited development of fruit sector in the country could be attributed to input supply constraints, limited skilled manpower and extension approaches and, focus of agricultural development efforts on grain production amongst others (Hailu, 2005).

Since there is limited detailed data on the supply and demand of banana from both the commercial farms and small holder farmer's data obtained from household, income, consumption and expenditure survey conducted by CSA has been utilized to estimate the present supply and demand (Abdisa, et. al., 2002). According to the survey the total domestic consumption of banana in the year 2000 was about 16,630.2 tones. Assuming an annual average growth of about 3%, the present domestic consumption of banana is estimated at 18,717.4 tones (Kibret et. al., 2014). When the average quantity of banana exported in the past three years is added to the domestic consumption, the total present effective demand is about 19,829.7 tones.

Ethiopia produces twelve varieties of banana (ten of improved varieties are released from research center to the farmers) for both domestic consumption and export (Teshome, 2012). With the exception of hybrids from the breeding programs, all cultivars of Ethiopian varieties discussed below are natural hybrids. Over thousands of years, they were selected by people and henceforth propagated vegetatively as clones (Teshome, 2012). They can produce fruit without fertilization, which is called "parthenocarpy." Many cannot interbreed because they are sterile. Bananas produce basal suckers (called keiki in Hawai the local word for "children"), which can be used to propagate an individual plant vegetatively (Adane, 2013). The edible bananas are highly diverse. Some of the most variable traits include: plant stature and architecture, sucker production, pigmentation, bunch size, orientation, shape, fruit size, color, and taste (Nakhauka et. al., 2013). Estimates of the numbers of cultivars that occur worldwide range from 300 to more than 1000 (Karamura et al.,2012). Common names that have been given to some of the cultivars are ambiguous. There are hundreds of duplicate names and close clonal relatives found in every region of every banana growing country (Babara et al., 2014). There are so many names that even compiling lists for specific countries or regions is a daunting task. For example, 'Lady('s) Finger' has been used to name at least four distinct AA, AB, and AAB clones (Abano et. al., 2011).

Most of the Ethiopian banana varieties are cavedish banana. Cavendish bananas were named after William Cavendish, 6th Duke of Devonshire (Efrem,2007). Though not the first known banana specimens in Europe, at around 1834, Cavendish had received a shipment of bananas from Mauritius courtesy of the chaplain of Alton Towers (then the seat of the Earls of Shrewsbury). His gardener, Sir Joseph Paxton cultivated them in the greenhouses of Chatsworth House. The plants were botanically described by Paxton as Musa cavendishii, after the Duke (Scot et. al., 2007).

The Cavendish subgroup is the most widely grown group of bananas since it includes the cultivars that dominate the international trade in bananas (e.g. Grande Naine, Williams and Valery) and as such have set the standards in terms of taste, yield and post-harvest characteristics expected of an export banana. They are also increasingly grown for domestic markets. Cavendish cultivars belong to the AAA genome group, which includes all the cultivars that have three sets of chromosomes donated by the wild species

Musa acuminata. Since triploid bananas are for all practical purposes sterile, from that point on diversity was created by natural mutations. The Cavendish subgroup is essentially composed of cultivars that diverged from each other through mutations. The exact number of cultivars is not known (Eshetu et. al., 2006). The cultivars in this subgroup are difficult to tell apart and exhibit a gradation in height from the shortest (Dwarf Cavendish) to the tallest (Lacatan). The fruits are long and slightly curved. A persistent floral relict is attached to the fruit apex, which is moderately tapered. The bunch is cylindrical, with 10 or more hands. Cavendish cultivars are susceptible to *Mycosphaerella fijiensis* and *Mycosphaerella musicola,* respectively the causal agents of black leaf streak and Sigatoka leaf spot. They are also susceptible to the banana bunchy top virus but then again so are all other types of bananas and to nematodes. Cavendish cultivars are resistant to the race strains of *Fusarium oxysporum* fussarium species cubense, the causal agent of Fusarium wilt.

Cultivars in this sub group form the basis of the world export trade amounting to only about 12% of all Musa productions worldwide (Stover and Simmonds, 1987). Cavendish cultivars are numerous and their identification is complicated by the limited number of morphological characters available and the effects of genotype and environment interactions on morphology (Daniells, 1990). Mutations from dwarf to tall and vice versa are very common, in addition to a number of named cultivars which are actually synonyms of the same clone. Isozyme characters (Jarret and Gawel, 1995) and oligonucleotide finger printing (Kaemmer et. al., 1992) also fail to distinguish between members of these closely related clones of this subgroup. Cavendish bananas on the whole are more productive than other cultivars, they produce big bunches with more hands and longer fingers, that turn yellow and have desirable flavor when ripe. The cultivars have considerable resistance to disease caused by bacteria and fungi. Ten different Ethiopian banana varieties are listed below, but the first five (1 – 5) varieties are the most common banana varieties highly distributed and commonly found on markets, and selected by farmers to produce, because of their test, size and number of the finger.

1. Giant cavedish
2. Butuza
3. Robusta
4. Poyo
5. Grande naine
6. Williams
7. Dwarf cavedish
8. Ducasso hybride
9. Cardaba cooking
10. Matoke cooking

3.4 Cultivar giant Cavendish (AAA)

Medium tall plant at least taller than Dwarf Cavendish 2.6-3m but readily top plus over when baring huge bunches. Therefore, farmers need to prop up the plant with sticks and this will require extra spacing. Huge fingers of average length between 22-24cm. Fingers are shorter than those of Valery. Big bunches of about 30kg. Flowering to harvesting: 4.5-5.0 months (Vezina et. al., 2014). Giant Cavendish produces high quality fruit, fairly round-tipped, pointing up wards, and arranged evenly in a cylindrical bunch. Their delicious fruits are exceptionally sweet (but not tart like "apple" bananas).

Fig. 1 Cultivar giant Cavendish

Along with Grand naine, they are the principal commercial banana varieties from Ethiopia as Robusta. It was initially introduced to replace Bluefields a variety highly susceptible to Panama wilt disease(Tigist, et. al., 2011). It also requires high amounts of fertilizer and sprays to combat black leaf streak fungi. Moreover,itisverysusceptibletospiralnematodesandrootrotdiseases.

3.5 Cultivar butuza(AAA)

It is a leading commercial cultivar grown throughout the country with location specific ecotypes like SNNPR in Gamo Gofa, Jinka and Arbaminch, Amhara region Tana zuria, Oromia east Shoa, Jimma and south west region. It is generally cultivated as a perennial crop. Arbaminch is the leading of butuza cultivar owing to its climatic and marginal soil condition (MARC, 2015). Butuza is also commercially cultivated for leaf industry throughout The region and in certain parts of Harar.

Fig.2 Caltivar butuza

Fruit is slightly acidic, firm and has typical sour-sweet aroma. Fruits turn to attractive golden yellow on ripening. Medium sized bunch, closely packed fruits, good keeping quality and resistant to fruit cracking is its plus points (Animesh et. al., 2012). But it is highly susceptible to Banana Bract Mosaic Viral (BBMV) disease and Banana Streak Virus, (BSV), which cause considerable reduction in yield.

3.6Cultivar robusta (AAA)

It is a semi tall variety, grown mostly in Gamo Gofa region and some parts of Oromia for table purpose. It is a high yielding and produces bunch of large size with well-developed fruits. Dark green fruits turn bright yellow upon ripening depending on ripening conditions (Alagarsamy et. al., 2008). Fruit is very sweet with a good aroma. Bunch weighs about 25-30 kg. Fruit has a poor keeping quality leading to a quick breakdown of pulp after ripening, hence not suited for long distance transportation. Robusta is highly susceptible to Sigatoka leaf spot disease in humid tropics (Wang et. al., 2009).

Fig. 3Caltivar robusta

3.7 Cultivar williams (AAA)

Williams is one of most common bananas in Ethiopia and is similar to a regular store bought banana, but with more taste and sweetness when grown at home and picked ripe. This is the variety that the Dole banana is. Bunches and fruit are large. Fruit size is 6-8 inch-long ×1.5-2 inch in diameter. The bunches can be 40- 80lbs with over 100 fruit. Because they make so many at once, they are great for freezing to use later in smoothies. Williams is also one of the most commonly grown commercial Cavendish banana varieties (super market banana). Fruit are some what's a usage shaped but with a curve (MARC, 2015). Fruit tips are not fully rounded, with flower residues remaining attached. This is atypical dessert type banana. Plants grow relatively tall (as compared to the other varieties banana).

Trunks (pseudo stem) vary from green to greenish-yellow to quite dark. Knob by stalk below the fruit (rachis) is less disordered as compared to Dwarf Cavendish. They are disordered because the flower bracts tend to remain on the rach is right just above the male flower bud and not fall off (Tekle et. al., 2014).

Fig. 4 Cultivar williams

3.8Caltivar poyo (AAB)

Poyo is a Hawaiian cultivar with green and white variegation that covers the entire plant leaves, leaf stalks (petioles), immature and ripe fruit, even the male and female flowers. A achlorophyllous tissues have a tendency to sunburn. Grows to height of 20–23 feet, prefers acid soil (<pH 6), will not tolerate neutral or basic soils, and thrives best in cloudy or lightly shaded areas (Randy et. al., 2007). The fruit

are palatable raw when fully ripe. The fruit, about six to eight inches long, are always variegated lengthwise giving them the appearance of being striped. As the fruit ripens the green stripes turn dark yellow while the white stripes turn light yellow maintaining the striped appearance. The fruit pulp is a light orange color. Its lower moisture content makes it closer to a plantain than to a dessert banana. It may be eaten ripe at a deep yellow color. The plant grows rather slowly because the white areas of the leaves are unable to photosynthesize and so the leaves are not fully functional (Echessa et. al., 2011).

Fig.5 Cultivar poyo

4. Nutrient composition of banana

Bananas and plantains constitute the fourth most important global food commodity (after rice, wheat and maize) grown in more than 100 countries over a harvest area of approximately 10 million hectares, with an annual production of 88 million tons (Nweze et. al., 2015). The all year round fruiting habit of bananas puts the crop in a superior position in bridging the 'hunger gap' between crop harvests. It therefore contributes significantly to food and income security of people engaged in its production and trade, particularly in developing countries. In Africa, they provide more than 25% of the carbohydrate requirements for over 70 million people. Eastern and Southern Africa produces over 20 million tons of bananas which accounts for 26% of total world output (Baiyeri et. al., 2011).

The Great Lakes region covering parts of Uganda, Rwanda, Burundi, Tanzania, Kenya and DRC is the largest producer and consumer of bananas in Africa (Smale, 2006) where per capita consumption has been estimated at more than 250kg; the highest in the world (FAO, 1985). Uganda ranks second after India in the world banana production with an annual output of 9.84 million tones accounting for 11.18% of the world's total production (INIBAP, 1999). A healthy diet consists of eating a variety of foods from 5 food groups but in the correct proportions. These include; foods containing starch, fruit and vegetables, milk and diary food, foods containing protein, and that containing fats and sugars. Bananas fall in the fruit and vegetable group as well as the food group which mostly contain starch. Sweet dessert bananas are generally eaten raw (fruit), while cooking bananas and plantains are boiled, steamed, fried or roasted (food). A person should eat at least 5 portions of fruit and vegetables every day where one whole banana fruit is equivalent to one portion just as two tomatoes and or half cucumber.

Bananas provide a good source of nutrients for both human and animal consumption and the nutritional values per 100 grams of edible portion are indicated in Table 1 where the same amount of grams yield up to 120 kcal of energy (ED informatics, 2006). Compared with many snack foods, banana provides energy primarily in the form of carbohydrate with minimal contribution to energy from fat. Any food containing carbohydrates should be the main part of our daily meals. More additional nutrients are provided in Table 2 and 3 after the banana nutrition group UK and Dickinson, (2000). The nutritional values indicated in the tables below vary between different cultivars, 1degree of ripeness and the growing conditions. In unripe bananas the carbohydrates are mostly starches. In the process of ripening the starches are converted to sugars; a fully ripe banana has only 1-2% starch (Sanjeev et.al., 2012).

Table 1: Nutritional values of bananas per 100g of edible fresh portion.

	Nutrients	Amount	Daily recommended values
1	Carbohydrates	23 gram	300 grams
2	Protein	1 gram	50 grams
3	Fats	0.1 gram	65 grams
4	Fiber	2.5 gram	25 grams

Source ED informatics, 2006

Table 2: Vitamin content of the banana (nutrients per 100g ripe, edible banana).

	Vitamins	Amount	Daily recommended intake per normal adult
1	Carotenes	21 micrograms	800 micrograms
2	Vitamin E	0.27mg	15mg
3	Thiamin (B1)	0.04mg	1.5mg
4	Riboflavin (B2)	0.06mg	1.7mg
5	Niacin	0.7mg	20mg
6	Pyridoxine (B6)	0.29mg	1.3-1.7mg depending on age
7	Folic Acid	14 micrograms	400micrograms
8	Pantothenate	0.36mg	10mg
9	Biotin	2.6 micrograms	300micrograms
10	Vitamin C	11mg	75mg women, 90mg for men

Source ED informatics, 2006.

4.1 Minerals profile of banana

Minerals play a vital role in proper development and good health of the human body and fruits are considered to be chief source of minerals needed in the human diet. Inadequate intake of mineral has been observed to be a major nutritional problem in our environment. Banana has been reported to prevent anaemia by stimulating the production of haemoglobin in the blood. Its role to regulate blood pressure has been associated the high content of potassium. Its peels in conjunction with other sub-stances create a liniment for reducing the acuteness of the arthritis aches and pains (Coulibaly et. al.,2007).

In Ethiopia, the intake of minerals such as iron and zinc is below the recommended levels and their bioavailability in the diet is low based on traditional food item. Biochemical studies show that some groups of the population have so low levels of minerals that intervention is needed (Berhanu et. al.,2015). Most attempts to combat mineral deficiency elsewhere in Ethiopia have focused on providing mineral supplements to the poor and on fortifying foods with these nutrients during processing after they have been harvested (Ifeoma et. al., 2011). But are these the best strategies? In Ethiopia, the focus is instead on biofortification, an intervention strategy that must developed is to increase the content of particular micronutrients in staple food crops by agricultural, agronomic or biotechnological means (Berhanu et. al., 2015). This means that the micronutrients are already in the crops when they are harvested, so they do not need to be added afterwards. When consumed regularly, bio fortified foods will lead to increased micronutrient intake. Bio fortification can complement the existing strategies and provide a sustainable, low-cost way of combating malnutrition (Kalagbor et. al., 2014).

Table 3: Mineral content of banana (nutrients per 100g ripe, edible banana).

	Minerals	Amount	Daily recommended in take per normal adult
1	Sodium	1mg	2400mg
2	Potassium	400mg	3500mg
3	Calcium	6mg	1000mg
4	Magnesium	34mg	400mg
5	Phosphorus	28mg	1000mg
6	Iron	0.3mg	18mg
7	Copper	0.1g	2mg
8	Zinc	0.2mg	15mg
9	Chloride	79mg	3400mg
10	Manganese	0.4mg	2mg
11	Iodine	8 micro gram	150micro gram

Source the banana group (UK); Dickinson, 2000.

4.1.1 Zinc

Zinc is an essential component of a large number of (>300) of enzymes participating in the synthesis and degradation of carbohydrates, lipids, proteins, and nucleic acids as well as in the metabolism of other micronutrients. Zinc stabilizes the molecular structure of cellular components and membranes and in this way contribute to the maintenance of cell and organ integrity. Furthermore, zinc has an essential role in polynucleotide transcription and thus in the processes of genetic expression. Its involvement in such fundamental activities probably accounts for the essentiality of zinc for all life forms. Zinc plays a central role in the immune system, affecting a number of aspects of cellular and hormonal immunity.

The clinical features of sever zinc deficiency in humans are growth retardation, delayed sexual and bone maturation, skin lesion, diarrhea, alopecia, impaired appetite, increased susceptibility to infections via defects in the immune system, and the appearance of behavioral changes.

A study conducted by (Umeta et. al.,2000) showed the presence of zinc deficiency in Ethiopia. In their intervention study, it was found that combating zinc deficiency can increase the growth rate of stunted children to that of non-stunted children in Ethiopia and called for the need of zinc supplementation.

Lean red meat, whole grain cereals, pulses, and legumes provide the highest concentration of zinc; concentration in such foods are generally in the range of 25 – 50mg/kg (380 – 760 m/mol/Kg) raw weight. The utilization of zinc depends on the overall compassion of the diet. Experimental studies have identified a number of dietary factors as potential promotes or antagonists of zinc absorption. Soluble organic substances of low relative molecular mass, such as amino and hydroxyl acids, facilitate zinc absorption. In contrast, organic compounds forming stable and poorly soluble complexes with zinc can impair absorption. In addition, competitive interactions between zinc and other ions with similar physiochemical properties can affect the uptake and intestinal absorption of zinc (FAO/WHO, 2001).

Zinc is required to make retinol binding protein (RBP) which transports vitamin A. Thus the deficiency of Zinc limits the body's ability to move vitamin A form the liver to the body tissues (Moreira et. al., 2009). About a third in duration and severity of diarrhea in children receiving zinc supplements and a median decline in the incidence of pneumonia. Zinc supplements help blunt the most severe malaria cases in children under five, reducing by over a third the number of such cases seen at health centers. Overall clinic visits by those receiving zinc decreased by a third and signs of other infections were reduced by 20-50% (SOWC, 1998). Zinc deficiency is increasingly recognized as widespread among women in developing countries and is associated with long labor which increases the risk of maternal and infant death. A number of studies have found out that supplements reduce complications of pregnancy (SOWC, 1998). The supplements however do not reach the majority in developing countries. Zinc deficiency affects development of acquired immunity by regulating growth and function of T and B cells. Zinc is used for DNA replication, RNA transaction, cell division cell activation (Ananda et. al., 2002).

4.1.2 Iron

Iron has several vital functions in the body. It serves as a carrier of oxygen to the tissue from the lungs by red blood cells, haemoglobin as a transport medium for electrons within cells, as an integrated part of important enzyme systems in various tissue (FAO/WHO 2001).

Most of the iron in the body is present in the erythrocytes as haemoglobin, molecule composed of four units, each containing one haem group and one protein chain. The structure of haemoglobin allows it to be fully loaded with oxygen in the lungs and partially unloaded in tissues. The iron containing oxygen storage protein in the muscles, mycoglobin, is similar in structure to haemoglobin but has only one haem unit and one globin chain.

Iron plays a greater role in the normal growth and functioning of human physiology. A technical report on human vitamin and mineral requirements states that the requirements for absorbed iron in infants and children are very high in relation to their energy requirements and infants have no iron stores and have to rely on dietary iron lone. Iron deficiency is the most prevalent nutritional deficiency around world; affecting children from poor communities. Populations most at risk for iron deficiency are infants, children, adolescents, and women of childbearing age, especially pregnant women (FAO/WHO, 2001). The prevalence of iron deficiency is not yet documented in Ethiopia. It is possible to meet high requirement of iron in the diet has consistently high content of meat and food reach in iron and ascorbic acid such as dark green leafy vegetables.

Nearly two billion people are estimated to be anaemic and millions are deficient, the vast majority of them women (WHO, 2001; Mason et. al., 2005). A range of factors cause iron deficiency, anaemia including inadequate diet, blood loss associated with menstruation and parasitic infections such as hookworms (WHO, 2001; Mason, et. al., 2005). Apart from lack of iron, B12, foliate and genetic abnormalities ingestion of toxic substances such as lead, and ethanol cause sideroblastosis (Mulokozi et. al., 2002). Iron deficiency not only impairs the production of red blood cells but also affects general cell growth and proliferation of tissues like nervous system and the gastro intestinal tract. Children who suffer from anaemia appear tired, inattentive and suffer from delayed motor development. It can also contribute to emotional development problems with malnourished children acting more irritable (Krishnan and Ramakrishnan, 2002). Each of the important causes of nutritional anemia can be eradicated through prevention and treatment. Many countries have begun the process of instituting food supplementation programs in which grains and cereals are fortified with iron or foliate or B12. Given the inadequate resources these deficiencies can also be prevented if natural sources can be enhanced.

4.1.3 Potassium

The banana requires more potassium for its growth, production and quality compared to nitrogen and phosphorus. With bananas, being a potassium loving crop, the farmers in India are applying potassium at 800 to 1600 kg per ha depending upon the available soil K status. As Muriate of Potash (MOP) is commonly used as the source of potassium, chloride toxicity is often seen in bananas, hindering the crop growth, yield and quality (Nalina 2002).

The mineral potassium is the main intra cellular cation in the body and is required for normal cellular function. The ratio of extracellular to intracellular potassium affects nerve transmission, muscle contraction, and vascular tone. Fruits and vegetables, particularly leafy greens, vine fruits, and root vegetables, are good food sources of potassium. Although uncommon in the general population, the main effect of severe potassium deficiency is hypokalemia. Hypokalemia can cause cardiac arrhythmias, muscle weakness, and glucose intolerance. Moderate potassium deficiencies, which typically occurs without hypokalemia, is characterized by elevated blood pressure, increased salt sensitivity, an increased risk of kidney stones, and increased bone turnover. An inadequate intake of potassium may also increase the risk of cardiovascular diseases, particularly stroke.

Potassium is a nutrient that is essential for health at the most basic level it keeps the body's cells functioning properly. Along with sodium and other compounds, potassium is an electrolyte, working to regulate the balance of body fluids. These actions affect nerve signaling, muscle contraction, and the tone of blood vessels, with far-reaching impacts on the body, including the cardiovascular system. This is critical to the function of nerve and muscle cells, including those in our heart. Some studies indicate that low potassium may contribute to hypertension, and that increasing potassium intake through diet may help prevent or help treat this problem. Other studies indicate that increased potassium intake is linked with a lower risk of stroke, but more research is needed.

Adequate Intake: 4,700milligrams/day adults (Ganeshamurthy et. al., 2011). Both banana peel and pulp have impressive potassium content. It is highly recommended by doctors for patients whose potassium is low. There is strong evidence that potassium lowers blood pressure, whether consumed in foods primarily as potassium bicarbonate, or as a dietary supplement in the form of potassium chloride or other potassium salt (Sathiamoorthy et. al., 2008). Specifically, potassium has been noted to reduce both systolic and diastolic blood pressure in people with normal and high blood pressure. Potassium's blood pressure lowering effect is greatest in those that need it most: those with hypertension, those who are salt-sensitive, African American males (who are also more likely to have hypertension and to be salt-sensitive), and those who consume the most sodium. It is important for those with hypertension to know that blood pressure is lowered with increased potassium and with an increase in the ratio of potassium to sodium (Okareh et. al., 2015). Potassium also reduces salt sensitivity, an independent risk factor for heart disease. Even without diagnosed hypertension, salt-sensitive individuals may experience spikes in blood pressure when they eat salty foods. Eating enough potassium-rich foods reduces or prevents the blood pressure response to dietary sodium, possibly by stimulating excretion of sodium chloride, or inhibiting sympathetic nerve response (Ando et. al., 2010). One final note about potassium and the cardiovascular system is that it may improve more than blood pressure. Emerging research suggests it affects the structure and mechanical function of the heart, which can lead to improvements in many cardiovascular risk factors.

4.2 Reducing sugars in banana

Free sugars, organic acids and amino acids are natural components of many fruits and vegetables and they play important roles in maintaining fruit quality and determining nutritive value (USDA, 2010). During banana repining, the starch converted into reducing sugars and sucrose increasing with ripeness. Reducing sugars are the fermentable sugars present in banana include glucose, fructose and sucrose namely, can also act as reducing agents and these sugars will contain an aldehyde functional group (Tapre et. al., 2012). In most cases, the non-fermentable sugars remaining in a banana are negligible, so that the residual sugar concentration consists primarily of the reducing sugars glucose, sucrose and fructose. The banana consists of approximately 75% water, 25% carbohydrate, and only a trace of protein and fat. It also has relatively high levels of calcium and phosphorus and is especially rich in potassium (Liyong et. al., 2010). The carbohydrate in the typically green, unripe banana is mostly in the form of starch, which is a long chain of covalently bonded glucose molecules. However, as the banana ages and ripens, the starch is converted to glucose, which gives the ripe fruit a very sweet taste. In this demonstration, students will test the unripe and ripe banana for starch and sugar content (William et. al., 2014).

4.3 Resistant starch in banana

For nutritional purposes, starch in foods may be classified into three types according to in vitro digestibility: rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS). Resistant starch is defined as the sum of starch and products of starch degradation not absorbed in the small intestine of a healthy individual (Nednapis et. al., 2012). In the gastrointestinal tract, the rapidly and slowly digestible fractions are digested and absorbed in the small intestine, generally within 120 min of consumption of foods, whereas RS is fermented in the colon. There are four types of RS: type I represents physically inaccessible starch which is locked in the plant cell walls of some foodstuffs such as partially milled grains, seeds and legumes (Moreira et. al., 2009). Type II is characterized by native granular starch found in foods containing uncooked starch such as bananas, raw potatoes and beans. The RS content in reference banana flour samples, determined by three laboratories, averages 52.1% (dry matter), while lentil flour has 8.2% RS (Victor et al., 2016). A study of (Vatanasuchart et. al.) on eleven banana cultivars grown in Thailand also shows that the RS content observed in the common cultivars ranges between 52.2-61.4% and values for indigenous cultivars are between 50.7-68.1%. Type-III RS is made up of retrograded starch or crystalline non-granular starch such as that found in cooked potatoes, bread crust, cornflakes and retrograded high-amylose maize starch (Kayshan et. al., 2014). Type-IV RS refers to specific chemically and thermally modified or repolymerised starch.

A substantial percentage of starch in bananas consists of resistant starch, which has the potential to provide significant health benefits similar to those derived from dietary fiber (Oborn et. al., 2014). Due to a high solid content of 40-70%, bananas can be processed into flour and starch suitable for making processed health food products. At present, a healthy choice of functional food products is of increasing interest to consumers. With properties similar to soluble and insoluble dietary fiber in the gastrointestinal tract, RS plays a major role in the health food industry (Anuchita, et. al., 2014).

Showing some resistance to human digestive enzymes, the slow release of glucose from RS results in reduced energy intake by the intestinal cells, which is evident from a low glycemic index of the non-digested starch. This can help improve glucose regulation in diabetes and facilitate weight control for the obese. The non-digested starch in the large intestine is fermented by colonic microflora, producing short-chain fatty acids that encourage the growth of beneficial bacteria (Corolina, et. al., 2013). This may lead to healthier colon cells and help prevent the development of colon cancer. In addition, a diet high in RS can reduce blood cholesterol and triglyceride levels due to higher excretion rates of cholesterol and bile acids. Overall, increasing the RS content in the diet has the potential to provide several significant health benefits and an added value to food products (Quoc, et. al., 2015).

As starchy foods are a main source of energy, a healthier choice of starchy foods that still provide beneficial functions for sustaining good health should be encouraged. Therefore, it is relevant to acquire new knowledge about the health benefits of different banana cultivars grown in Ethiopia and to hypothesis that Ethiopian banana varieties are a good source of RS which is good for health. The RS concentration was almost ten times higher in unripe bananas than in ripe ones (Zomo, et. al., 2014).

5. Polyphenol oxidase activity in banana

Polyphenol oxidases (PPOs) are a group of copper-proteins, widely distributed phylogenetically from bacteria to mammals, that catalyze the oxidation of phenolics to quinones which produce brown pigments in wounded tissues of banana and other fruits (Elawam et. al., 2014). PPO has been implicated in the formation of pigments, oxygen scavenging (Christiane et. al., 2010), and defense mechanism against banana pathogens, and herbivory insects on other fruits (James, 2016). Phenolic compounds serve as precursors in the formation of physical polyphenolic barriers, limiting pathogen translocation. The quinones formed by PPOs can bind plant proteins, reducing protein digestibility and their nutritive value to herbivores (Macheix et. al., 2015).

On the other hand, the oxidation of phenolic substrates by PPO is thought to be the major cause of the brown coloration of banana during ripening, handling, storage and processing. This problem is of considerable importance to the food industry as it affects the nutritional quality and appearance, reduces the consumer's acceptability and therefore causes significant economic impact, both to food producers and to food processing industry (Mayer and Harel 2015). It is estimated that over 25% of losses in banana fruits occur as a result of enzymatic browning and tropical and subtropical fruits and vegetables are the most susceptible to these reactions (Mehari, et. al., 2007). PPO has been regarded to be a critical enzyme in food technology and it has been intensively studied in several plants (Roberto et. al., 2009). PPOs are synthesized as pre-proteins and contain putative plastid transit peptides at the N-terminal region, which target the enzyme into chloroplast and thykaloid lumen. PPO from some plants has been described as a multiple gene family (Mayer and Harel 2015). The mechanism of action proposed for PPO is based on its capacity to oxidize phenolic compounds. When the tissue of banana fruit is damaged, the rupture of plastids, the cellular compartment where PPO is located, leads to the enzyme coming into contact with the phenolic compounds released by rupture of the vacuole, the main storage organelle of these compounds. The active site of PPO consists of two copper atoms and the enzyme catalyzes two different reactions in the presence of molecular oxygen: the hydroxylation of monophenols (monophenolase activity) and the oxidation of o-diphenols to o-quinones (diphenolase activity). This reaction is followed by non-enzymatic polymerization of the quinones giving rise to melanin, pigments of high molecular mass, and dark color (Norbart et. al., 2015).

Banana PPOs have broad substrates specificities and are able to oxidize a variety of mono, di or polyphenols. Phenolic compounds are natural substances that contribute to the sensorial properties (color, taste, aroma and texture) associated with fruit quality. Structurally they contain an aromatic ring bearing one or more hydroxyl groups together with a number of other substituents (Sheryl et. al.,2010).

Some of PPO substrates occur naturally in fruits and vegetables, are very suitable to enzymatic browning, are rich in chlorogenic acid, catechin and epicatechin (Vanini et. al., 2010).

The degree of browning depends upon such factors as amount and type of phenolic compounds, enzyme, pH of the medium, availability of oxygen, temperature and time of exposure to the air after peeling (Sheryl et. al.,2010). Enzymatic activity was the main factor involved in browning, whereas others related the browning tendency of banana cultivars to phenolic content. Differences in the affinity of the enzyme for the substrate were reported to be another factor that determined the degree of browning (Alamolumangai et. al.,2015). Normal fruit develop internal browning as a consequence of over maturity and senescence. Fruits that have stems show more browning than those with no stems (Jan et. al., 2007). There are contradicting results in the PPO activity reports for various fruits during ripening; however, most fruits show a decrease in activity during ripening. During early stages of peaches fruit ripening the PPO activity was found to be high, which then decreased (Khandker et. al., 2012). The decrease was accompanied by a decrease in o-dihydroxyphenols.

The inactivation of PPO is required to minimize product losses caused by browning. In this way, several methods and technologies have been studied. Heat treatment and addition of anti-browning agents are usually applied, but several researchers have proposed the application of other methods as alternatives to thermal processing for PPO inactivation. (Jan et. al., 2007).

Chapter 3 – *Materials and Methods*

6. Materials and Methods

6.1 Location of the Study

The study was conducted at four different locations. Storage of samples, moisture and ash analysis were conducted at the Center for Food Science and Nutrition of Addis Ababa University, mineral analysis were conducted at the Ethiopian Geological Survey Institution and resistant starch and reducing sugar analysis were conducted at the Ethiopian Public Health Institution and polyphenol oxidase activity analysis was conducted at Holota Agricultural Research Center.

6.2 Chemicals and Reagents

All chemicals and reagents used for analyses were analytical reagent grade.

6.3 Sample collection

Edible parts of the selected ten varieties of banana was harvested manually from Melkasa Agricultural Research Center. There are about twelve types of varieties in Ethiopia but the two banana varieties are not still released to the farmers, because of this only the ten different varieties are selected for the purpose of my studies. The banana fruits were randomly selected and matured fingers of the fruit were cut and placed in plastic bags and transported to the Center for Food Science and Nutrition Laboratory. The fruits were kept at room temperature until ripen. Sample of raw and ripe banana were dried at $50^0{}_c$ for 72 hrs. by drying oven and powdered by hand. All cares are taken for the fruit during collection, transportation, storage and processing.

7. Analytical Methods

7.1 Determination of the moisture content

First empty drying dish (made of porcelain) with its cover were dried using a drying oven for one hour at 105^0c. The dishes were cooled for 30 minutes in a desiccators and weighed using digital analytical balance to the nearest milligram (W_1). About 5 gram of fresh sample were weighed (W_2) in dried and pre weighed drying dishes. The dishes and their contents were then placed in drying oven and dried for 5 hours at 105^0c. After 5 hours the dishes and their contents were cooled in desiccators to room temperature and weighed (W_3). The procedure was repeated until a constant weight was attained (AOAC,2005). The sample should be weighed again and the moisture content may be calculated to decimal place by the following formula.

$$\%\text{Moisture Content (M)} = \frac{W_1\text{-}W_2}{W_2\text{-}W_1} \times 100$$

W_1=Weight of the empty container with its cover.

W_2=Weight of the container with its cover and seeds before drying.

W_3=Weight of the container with its cover and seeds after drying.

The duplicate result of the determination differs by more than 0.2% then the analysis was repeated in duplicate. The material was re dried. The moisture content was calculated from the results obtained in the pre dried and dried stages using the following formula:

$$M = S_1 + S_2 - \frac{S_1 x S_2}{100}$$

M=Moisture content

S1=Moisture percentage lost in pre drying stage.

S2=Moisture percentage lost in drying stage.

7.2 Determination of total ash

Ash was determined using AOAC (2005). The porcelain crucible was dried in an oven at 100°c for 10 minutes, cooled in desiccators and weighed (W1). Two grams of the sample were placed in to a previously weighed porcelain crucible and reweighed (W2); it was first charred on the hot plate in the fume hood until it was completely decarbonized and then transferred in to a furnace which was set at 550°c. The sample was left in the furnace for six hours to ensuring proper ashing. The crucible containing the ash was then removed; cooled in desiccators and weighed (W3). The percentage ash content was calculated as follows:

$$\%\text{Ash Content} = \frac{W_2 - W}{W_1 - W} \times 100$$

Where: - W= weight of empty dish in gram

W1 = weight of dish the dried test materials in gram

W2 = weight of dish plus the ash in gram

7.3 Determination of minerals

The method of AOAC (2005) were used to determine mineral. Accordingly, all the crucibles required for mineral analysis were washed with 6N HCl and glass wares with 10% nitric acid. The required number of crucible was placed in an oven for 30 minute at $100^{o}C$, cooled in desiccators for 30 minutes and weighed (W_1). One gram of sample was accurately weighed and subjected to chare at hot plate starting from low temperature under a hood. The sample were ashed in a muffle furnace at 475°c for one hour and the crucibles were taken out from the furnace, cooled, and moistened with a few drops of deionized water. The water was evaporated on a hot plate. The sample were ashed once more for 30 minute at 475°c and cooled in the crucible; some drops of deionized water and 5 drops of concentrated HNO_3 were added and evaporated on hot plate as described above. Finally, the samples were ashed as above for 30 minutes at the same temperature as previously described. The crucibles were cooled in desiccators for 45 minutes and then weighed (W_2). Six ml of 6N HCl was added to the ashed sample to wet it completely and carefully taken to dryness on a low temperature hot plate until the solution just boils. Then the solution was cooled and filtered through a Whatman No. 1 filter paper into a 50 ml graduated flask. 5 ml of 3N HCl was added to the crucibles and the solution was heated until it starts to boiling, cooled and filtered into a graduated flask. The crucibles were washed three times with deionized water and the washing was filtered into the graduated flask. The sample extract solution was transferred to polyethylene bottle and stored until used for determination of minerals. Blank was prepared without sample by taking the same amount of reagent under the same condition.

The mineral zinc and iron were analyzed using Shimadzu atomic absorption spectrophotometer (AA-6800/ "AA Wizard" software). The potassium content was determined using flam photometer (Jenway, PF 7, Essex UK) according to the method described by AOAC 2005,966.16 and 965.30, respectively.

Briefly, two grams of dried samples were weighed in 250 ml conical flask and 20 ml of diluted nitric acid (1:1 ratio with deionized water) was added. The mixture was digested by gently boiling on a hot plate for 10 minutes. The digest was cooled and filtered into 100 ml volumetric flask. The conical flask and the residue left on the filter paper was washed several times with deionized water and the volumetric flask containing the filtrate was made to the mark with deionized water. 5 ml of previously prepared diluted potassium chloride solution was added and the volume was filled to the mark with deionized water. For potassium determination, 5 ml of the same extract was added into 100 ml volumetric flask and the volume was made up to the mark with deionized water. Blank solution was prepared in a similar manner without addition of the sample extract. Potassium was determined from the aliquots of solutions using flam photometer.

$$\text{Metal content } [(\text{mg}/100\text{g})] = [A-B] \times V/10w$$

Where- W= Weight of sample in (g)

V= Volume of the extract (ml)

A = Concentration of the sample solution (ug/ml)

B = Concentration of the blank solution (ug/ml)

For K, report results to the nearest 0.001%

% analyte = mg/L - method blank) x (25) x (0.0001)

dry matter (%)/100

For Zn, and Fe, report results to the nearest 1 mg/kg

Mg/kg analyte = mgL - method blank) x (25)

dry matter (%)/100

7.4 Determination of reducing sugar

Extraction of sugar from banana was done by using Loomis and Shull (1937) method. Two banana figures from each selected variety were cut into small pieces and immediately plunged into boiling ethyl alcohol and was allowed to boil 5 to 10 minutes (10 to 20 ml of alcohol was used per gm of pulp). The extract was filtered through the two layers of cloths and the ground tissue was re-extracted for 3 minutes in hot 80% alcohols, using 2 to 3 ml of alcohol per gm of tissue. The extract was cooled and passed through the two layers of cloths. Both of the extracts were filtered through Whatman No. 41 filter paper. The volume of the extract was evaporated to about 25% of the volume over steam bath and cooled.

7.5 Determination of resistant starch

The RS content of banana samples was determined by a direct method of (Fungo, et. al., 2010). A ground sample flour of banana (100 mg) was incubated with a solution containing 20 mg pepsin at 40°C for 60 min. to remove protein. A tris-maleate solution containing 40 mg pancreatic α-amylase was then added and the mixture incubated at 37°C for 16 hrs. to hydrolyze digestible starch. The hydrolysate was centrifuged and the residue was solubilized with 4M KOH and incubated with amyloglucosidase (80 μL) at 60°c for 45 min. to hydrolyze RS. The total starch content was determined according to a modified method of (Jouni et. al., 2011) A 50-mg ground sample of banana was dispersed in 2M KOH (6 mL) and the mixture incubated for 30 min. at room temperature. The solubilized starch was then hydrolyzed by adding amyloglucosidase (60 μL) and incubating at 60°c for 45 min. in a shaking water bath. After centrifugation (15 min., 4500g), the glucose content in the supernatant was measured using the glucose oxidase-peroxidase kit, and the total starch content was calculated as mg of glucose x 0.9. Digestible starch content was calculated as the difference between total starch and RS or indigestible starch, expressed as per cent of the sample dry weight. The amylose content of banana flour and starch samples was determined by a colorimetric AACC (2002) method. Briefly, a 100 mg sample was gelatinized in the presence of 95% ethanol (1 mL) and 1N NaOH (9 mL) to liberate amylose molecules. Iodine solution (2 mL) was added to form an amylose-iodine complex and absorbance was read at 620 nm. The amylose content was calculated by means of a standard curve and expressed as percent of sample dry weight.

7.6 Determination of polyphenol oxidase activity

Polyphenol oxidase activity was measured indirectly by determining the decrease in iron binding polyphenols (catechol and galloys). One gram (1 gm) of sample was incubated for one hour in a phosphate buffer (sodium phosphate) with constant shaking. The PH was set at 6.5, as this is thhe optimum condition for activity of polyphenol oxidase (Towo et. al., 2006). The samples were then freez dried and the amount of catechol and galloyl was determined (Matuschek et. al., 2001, Brune et. al., 1991). Polyphenol oxidase activity was expressed as μmole of catechol and galloyl/g DM.

Chapter 4 – *Results and Discussion*

8. Result and Discussion

8.1 Moisture and ash

Table 4. shows mean concentrations and standard deviation, maximum and minimum concentrations of moisture and ash. The mass fraction of both moisture and ash is obtained in this work was within the same range of data reported in Food Composition Charts (Mataix, et. al., 2003). It can be emphasized that in the samples of bananas analyzed moisture for Giant Cavendish and Robusta, and ash for Williams were lower but moisture for Williams was higher than the values indicated in the Food Composition Chart. The moisture concentration was different may because of the size difference between banana fingers and peel thickness according to (Marielli, et. al., 2015), or the moisture content increased with ripening. This explains the softening texture of banana fruits as ripening proceeds and it agrees with Simmonds (1966), and (Ahenkora, et. al, 1997). Although the higher the size and ripening has presented the highest mean concentrations. Ash behaved in a similar manner. Mean concentrations in the varieties were higher ($p<0.05$). Higher contents of ash in the varieties could be due to the high absorption ability of minerals from the soil or soil type and the ash values increases gradually with ripening and can be said to be concomitant with the mineral element composition according to (Marisa et. al., 2006). In general, the ash result was less than the other studies, this may because of the analysis was done only on edible portion of the fruits.

Table 4. Moisture on fresh basis and ash in dry basis (g/100g) of raw banana

No.	Varieties	Moisture FB %	Total Ash
1	Giant Cavendish	66.50 ± 0.4^{a}	0.75 ± 0.29^{b}
2	Butuza	73.63 ± 0.27^{a}	0.80 ± 0.99^{a}
3	Robusta	69 ± 2.18^{a}	0.78 ± 0.12^{a}
4	Williams	77.19 ± 2.05^{a}	0.68 ± 0.44^{a}
5	Poyo	74.04 ± 0.27^{a}	0.69 ± 0.59^{b}

FB= Fresh basis ash is on dry basis; Values are expressed as mean ± SD of two determinations; Mean value in the same column for each species followed by different superscript letters were considered significant at P< 0.05.

8.2 Mineral content

Bananas are considered a good source of K in the diet, and the data support these assertions. Average K content for Ethiopia's Butuza variety was 355.271 mg/100 g fresh weight (Table 5). New DRI values have been published recently for K, and the daily adequate intake for adults is 4700 mg (IOM, 2014). Therefore, 100 g of banana fruit would provide 7% of the K requirement for the average adult. A range of mineral concentrations has been reported for bananas (Hardisson, et. al., 2001; USDA-ARS, 2004; Wenkam, 1990), and the results generally agree with previous reports for K. This may because of banana being a K-loving crop requires heavy dosage of potassium and use of applied fertilizer. However, the average values for Fe, and Zn are higher than those reported by Wenkam, (1990) and the USDA Nutrient Database (USDA-ARS, 2004).

The theoretical cases for diversification of minerals, therefore needs to be revisited in order further understand the how it can be made and varied amounts of iron and zinc. The previous findings showed that banana is definitely low in iron (Birhanu, et. al., 2015) and banana would not be a significant source of potassium for human survival one would need to obtain other sources of potassium in order to reach the 4700mg quota (Sajib, et. al., 2014) but contradicts with the work of (Marisa M., 2006). Also the mineral content of the soil has positive influence on the mineral contents of banana (Moreiral, et. al., 2008). It is however, noted from this study that such a mineral content difference between the varieties is not only because of the soil mineral contents factor but also benefit is not likely for most rural households with the obvious alternative of survival being polyphenols with cathecol and galloyl groups always bind iron and zinc and they are additional causes for mineral variation between banana varieties. And also as indicated by (Hallberg and Hulthen, 2000) calcium in banana also inhibits iron absorption by the plant. Those reasons might the more probable outcome of diversification.

Table 5. Mineral content (K, Fe, and Zn) of banana fruits (mg/100 g dry weight)

No	Varieties	Fe	Zn	K
1	Giant Cavendish	0.707 ± 0.08^{a}	0.217 ± 0.02^{b}	294.871 ± 0.3^{bc}
2	Butuza	0.677 ± 0.12^{a}	0.247 ± 0.01^{ab}	287.171 ± 2.6^{a}
3	Robusta	0.627 ± 0.06^{a}	0.307 ± 0.05^{b}	311.471 ± 0.3^{a}
4	Williams	1.017 ± 0.05^{b}	0.177 ± 0.01^{c}	322.171 ± 1.6^{c}
5	Poyo	1.047 ± 0.30^{a}	0.267 ± 0.03^{c}	355.271 ± 7.8^{c}

Values are expressed as mean ± SD of two determinations; Mean value in the same column for each species followed by different superscript letters were considered significant at $P< 0.05$.

8.3 Reducing sugar content

Highly significant variations were observed in the reducing sugar content between the five varieties at different days of storage. The maximum reducing sugar content (17.43%) was recorded in giant Cavendish and the minimum (10.59%) in williams at the 12th day of storage Table 6. The increase in reducing sugar may be attributed to enzymatic conversion of starch to reducing sugar (Islam, 1998).

Bhadra and Sen, (1999) mentioned that the total sugar and reducing sugar contents increased with in the progress of the storage period. At the same time there was higher reducing sugar in giant Cavendish, poyo and robusta, also rapid change of starch to reducing sugar were observed on the same storage day. Among the varieties williams and butuza appeared to be more suitable for extending the shelf life. The increase in reducing sugar with the progress of ripening as well as storage time was due to the degradation of starches to glucose and fructose by the activities of amylase and maltase (Wills, et. al. I981) and (Tandon, et. al., 1985) mentioned that fructose content was increased during ripening and the chemical properties of banana were greatly influenced by different kinds of postharvest treatments and varieties. Joshi and Roy, (1988) also reported that percentage of reducing sugars increased gradually up to 25 days in the banana fruits held in cold room and declined sharply after because of the onset of senescence. (Chacon, et. al., 1987) mentioned the total reducing sugar in green and ripe bananas were 0.52% and 10.3%, respectively. Stratton and Loesecke, (1930) reported that reducing sugar content increased progressively from 0.24% to 15.3%.

The total reducing sugar of banana varieties in this study were comparable to that studied by (Tapre, et., al. 2010). The starch is converted to sugars as the banana fruit starts to ripen. The type of sugar present in ripe banana includes glucose, fructose and sucrose, among which more than 70% of the total sugar is sucrose (Marriott, et. al., 1981). In addition, the sugar content is considered a practicable parameter for evaluation of fruit ripening since it gains good correlation with optical properties and physical properties during ripening (Kader, 1997; Liew and Lau, 2012).

Table:6 Reducing sugar content (%/100g) of banana varieties

No.	Varieties	Days of Storage			
		3	6	9	12
1	Giant Cavendish	13.87±2.76[a]	14.21±0.77[a]	15.85±1.22[a]	17.43±1.68[a]
2	Butuza	11.55±2.45[a]	12.23±2.67[b]	12.70±2.83[b]	15.90±3.10[b]
3	Robusta	14.01±2.99[a]	15.21±1.63[c]	16.73±1.17[b]	17.41±2.87[c]
4	Williams	8.11±1.8b[c]	8.39±1.56[ab]	9.87±0.81[a]	10.59±2.44[d]
5	Poyo	13.22±1.77[ac]	14.77±3.22[b]	15.31±1.21[a]	16.69±.98[c]

Significant at 0.05 levels; a,b,c. express the data ranges, in a column values having the same letter(s) do not differ significantly P< 0.05

8.4 Resistant starch content

The total resistant starch contents of banana from the five cultivars are shown in Table 7. The RS content of banana ranges between 52.2-61.4%. Poyo caltivar has the highest resistant starch content, followed by giant cavendish and robusta. Most of the cultivars samples have significantly higher RS. Study by (Englyst, et. al,. 2011) and (Goni, et, al,.2011) on resistant starch in banana showed values of 51.3-53.1%. Also, work by (Tribess et al,. 2011) showed a high resistant starch content in Williams banana variety (40.9-58.5%), similar to the findings by (Faisant et al,. 2011) (47.3-57.2%), whereas (Roa, et. al., 2007) found a lower resistant starch content (30.4%). However, the overall results from the present study indicate that the indigenous giant Cavendish and robusta cultivars are rich in resistant starch when compared to the other cultivars. This shows that it is reach in dietary fiber and plays a major role in the health of food industry (Anuchita, et. al., 2014). The high amount of fiber may as a result of the thin peel during ripening may left much of its fiber on the edible portion of this variety when compared to the other.

The RS content was decreased due to the maturation stage. Some starches are broken down to simple sugar by several enzymes of carbohydrate hydrolases (Emaga, et. al., 2007) with the result of lowering the starch content in both RS and TS whilst the content and reducing sugar increases. This idea is in agreement with the study of Emaga et al. (2007; Prabha and Bhagyalakshmi (1998). But this contradicts with the work of (Nednapis et. al., 2012) that the peel thickness and the fiber releasing ability on the edible part has a factor on resistant starch amount by increasing cellulose on edible part.

Table 7. Total starch, digestible starch and RS (g/100g dry weight) of different banana cultivars.

No	Varieties	Total Starch	Digestible starch	Resistant Starch
1	Giant Cavendish	91.0 ± 3.1^{b}	33.3 ± 1.9^{a}	57.7 ± 1.1^{a}
2	Butuza	80.5 ± 0.3^{c}	28.2 ± 4.5^{ab}	52.2 ± 4.1^{b}
3	Robusta	72.1 ± 3.4^{a}	15.1 ± 3.2^{c}	57.0 ± 0.2^{c}
4	Williams	72.3 ± 1.8^{a}	23.0 ± 4.8^{bc}	56.6 ± 5.8^{c}
5	Poyo	72.7 ± 1.4^{a}	10.9 ± 0.5^{c}	61.4 ± 2.3^{c}

Values are means of duplicate analysis. In a column, means not sharing a common letter are significantly different at $P< 0.05$

8.5 Polyphenol oxidase activity

Banana varieties containing high polyphenol contents are known to have high polyphenol oxidase activity (Dicko et. al., 2002). Robusta and Butuza varieties had higher significantly higher PPO activities than the other banana varieties ($P < 0.05$). This suggests that the shelf life of those banana varieties is lower than the other and highly susceptible for enzymatic browning (Demeke, et. al., 2001). For an indirect evaluation of endogenous PPO activity, dry mater (flours) were incubated at PH conditions favorable for PPO activity. The PPO activity decreased with the decrease in extraction rate for Robusta and Butuza while it increases in the rest varieties (Figure 7). This difference may be due to difference in PPO localization and warrants further investigation.

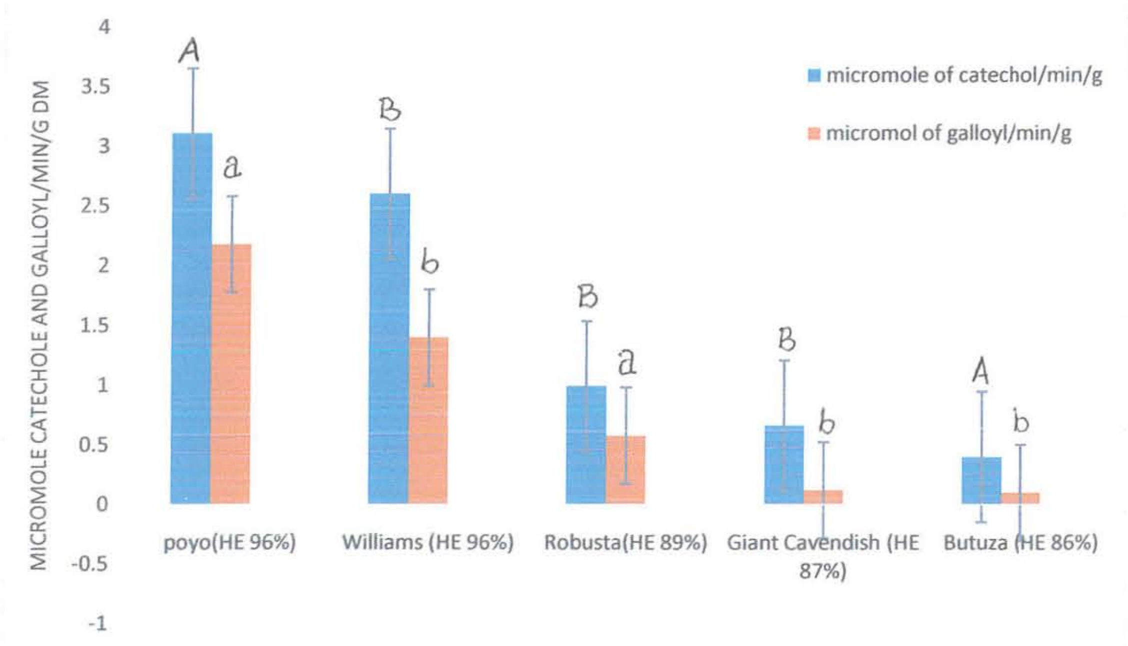

Fig.7 Polyphenol oxidase activity of selected banana varieties; DM (dry mater) and HE (higher extraction); error bars represent the standard deviation of means; Different superscript letters for the varieties represents statistically significant difference (P<0.05).

Chapter 5 – *Conclusion and Recommendation*

9. Conclusion and Recommendation

The study was set out to explore the mineral profile, reducing sugar contents, resistant starch contents and polyphenol activities of selected and major five Ethiopian banana varieties and has identified the amount, the difference between the varieties, for potassium, zinc and iron, resistant starch, reducing sugar and polyphenol oxidase activity and the reason why these difference is occurred between the varieties. The study has also sought to know whether iron binding phenolic compounds catechol and galloyl are used for estimating polyphenol oxidase activities of banana varieties and can result in affecting shelf life of banana particularly when stored at normal room temperature. The study sought to answer three of these questions:

1. Do selected Ethiopian banana have a difference in mineral profile reducing sugar and resistant starch?
2. In which banana variety is polyphenol oxidase activity being high and affect shelf life? and
3. Which banana variety can promote to improve mineral deficiency and resistant to browning.

This study indicates that the Ethiopian selected banana varieties are rich source of minerals potassium, zinc and iron. The foremost findings of this study comprise that selected banana varieties are rich in potassium. Among them robusta bananas has more mineral followed by butuza then williams. But Williams and poyo are good in their iron contents. Also the findings towards reducing sugar indicated that the total reducing sugar of fruits increased during the storage. The increasing trend was not rapid on williams and butuza bananas.

The high content of resistant starch found in all of five cultivars of bananas indicates that they are a healthy choice for consumption. Their genotypes seem to influence the resistant starch content. The highest resistant starch content was found in poyo, giant cavendish, robusta, williams and butuza respectively. A significant linear relationship between resistant starch contents of the banana samples indicating that the resistant starch stability comes from amylose molecules activity.

Poyo and williams have high iron binding phenolic compounds (galloyl and catechol). This shows that high polyphenol oxidase activity and less shelf life or highly browning rate of the varieties. This is might be why both banana varieties were high in iron and zinc content when we compared with the other varieties. Because in principle polyphenols with cathecol and galloyl groups always bind iron in 3:1 fashion (Bravo, 1998). In addition, phenolic compounds also inhibit the absorption of minerals such as iron and zinc (Brune, et. al,.1991).

10. Recommendations

This study showed the difference between selected Ethiopian banana varieties in mineral profile, reducing sugar, resistant starch and polyphenol oxidase activities. Exploring the following as future research strategies can facilitate the attainment of this goal:

1.This study has used empirical findings to show that selected Ethiopian banana varieties are good sources of potassium, resistant starch and reducing sugar but minimum amount of iron and zinc. The theoretical arguments for this justification suggest the need for policy review which will enable diversification to work for the improvement of research towards banana to improve nutritional contents especially the mineral contents and introduction of different varieties.

2.To generate more good results towards polyphenol oxidase activities modification of the processing activities and using of direct measurement will be studied.

3. The soil profile of banana growing areas will be studied to compare with the mineral contents of banana

4. Banana varieties collected from local farmer's land will be compared with the research centers.

5. The peel of Ethiopian banana varieties will be checked for nutritional content specially for mineral profile.

6.Evidences by Federal Ministry of Health indicates children under five years still have problem of balanced diet and micro nutrient deficiency therefore on the strategy of reduction of poverty and micronutrients deficiency, researchers focus on some selected fruits like banana by promoting consumption of bananas with enriched micronutrients, severe deficiencies can be reduced where diets are largely banana based.

11.References

Aarti, S.,Sayeed A., Anees, A.(2015). Green extraction methods and environmental applications of carotenoids-a review. *Department of Chemistry, Aligarh Muslim University, Aligarh, UP, India*, 8 :445-468.

Abbas, F,. Saifullah, R,. Azhar, M. (2009). Differentiation of ripe banana flour using mineral composition and logistic regression model, *International Food Research Journal*. 16: 83-87.

Adane Gebeyehu, (2015). Effects of Different Concentrations of BAP (6-Benzyl Amino Purine) and NAA (Naphthalene Acetic Acid) on Banana (Musa spp.). Giant Cavendish Shoot Proliferation, *International Journal of Plant Science and Ecology*. 1: 36-43.

Adelekan ,O, Arisa ,U., Alamu, A., Adebayo, O., Omolara, O. (2013). The Effect of Some Fruits Addition on the Nutritional, Microbiological and Sensory Qualities of Sorghum Based Pito. *International Journal of Food Science, Nutrition and Dietetics*,35:8-22.

Adan, G. (2015). Effects of Different Concentrations of BAP (6-Benzyl Amino Purine) and NAA (Naphthalene Acetic Acid) on Banana (Musa spp.). Giant Cavendish Shoot Proliferation. *International Journal of Plant Science and Ecology*, 1: 36-43.

Adeosun Olubunmi, (2013). Preliminary studies on polyphenol oxidase activity in plantain (Musa paradisiaca) cultivars, *African Journal of Agricultural Research* 8:366-369.

Alagarsamy, R., Neelakandan ,K. (2008). Studies on the efficacy of sulphate of potash (SOP) on the physiological, yield and quality parameters of banana cv. Robusta (Cavendish- AAA), *Euro-Asia. Journal of Biological Science*. 2:102-109.

Aline ,P., Marcelo, M. (2015). Banana (Musa spp.) from peel to pulp: Ethno pharmacology, source of bioactive compounds and its relevance for human health, *Journal of Ethno pharmacology*. 160:149–163.

Alamelumangai, M,. Dhanalakshmi, M,. Mathumitha, R,. Saranya, R,. Muthukumaran, P., Rajalakshmi, N. (2015). Modulation of Banana Polyphenol Oxidase (PPO) Activity by Naturally Occurring Bioactive Compounds from Plant Extracts, *International Journal of Pharma Sciences and Research*. 6:151-155.

Almazan, M. (1990). Influence of plantain and cooking banana cultivars and ripeness on processed product quality. *Journal of Food Qualilty*. 13:351–359.

Anuchita, M.,Wanassanun, T., Mai, S., Pimpila, S., Laongdao, P., Rattanapon, P., Nattipon, H. (2014). Resistant starch and bioactive contents of unripe banana flour as influenced by harvesting period and its application, *American Journal of Agricultural and Biological Sciences*. 9: 457-465.

Andre, T., Jean-Rodolphe, P., Wahbi, J.,Yves ,J. (2004). Shrinkage and density evolution during dryingof tropical fruits: application to banana, *Journal of Food Engineering*. 64:103–109.

Arumugam, R.,Manikandan,M.(2011). Fermentation of Pretreated Hydrolyzates of Banana and Mango FruitWastes for Ethanol Production. *Asian journal of biolological science*. 2: 246-256.

Alamelumangai, M., Dhanalakshmi,, M,. Mathumitha, R,. Saranya, R., Muthukumaran, P., Rajalakshmi, N. (2015). Modulation of Banana Polyphenol Oxidase (PPO) Activity by Naturally Occurring Bioactive Compounds from Plant Extracts, *International Journal of Pharma Sciences and Research.* 6:152- 156.

Adeyemi, O,. Oladiji, A. (2009). Compositional changes in banana (Musa ssp.) fruits during ripening, *African Journal of Biotechnology.* 8:858-859.

Ajay, K., Mahapatra, S., Mishra, U., Pratap, C. (2011). Nutrient Analysis of Some Selected Wild Edible Fruits of Deciduous Forests of India: An Explorative Study towards Non-Conventional Bio-Nutrition, *Advanced Journal of Food Science and Technology.* 4: 15-21.

Arawande, O., Komolafe, E. (2010). Anti-oxidative potentials of banana and plantain peel extracts on crude palm oil. *Ethnobotanical Leaflets.* 14: 559-69.

Auta, S., Kumurya, A. (2015). Comparative proximate, mineral elements and anti-nutrients composition between *Musa sapientum* (Banana) and *Musa paradisiaca* (Plantain) pulp flour, Sky *Journal of Biochemistry Research.* 4:1025 – 1030.

Atsbeha, G., Tessema, B. (2014). Roles, Policy and Small-scale Farming Systems, *Review of Ethiopian Agriculture.* 2: 11-12.

Awole S., Kebede W., Workneh, T. (2011). Postharvest quality and shelf life of some hot pepper varieties. *Journal of Food Science and Technology.* 10:111-405.

Baiyeri, P., Aba, C., Otitoju, T,. Mbah, B. (2011). The effects of ripening and cooking method on mineral and proximate composition of plantain (Musasp. AAB cv. 'Agbagba') fruit pulp, *African Journal of Biotechnology.* 10: 6979-6984.

Beatrice, N.,Ekesa, J., Kimiywe, I.,Van den B., Guy B., Claudie, D.M., Mark, D(2013). Content and Retention of Provitamin A Carotenoids Following Ripening and Local Processing of Four Popular Musa Cultivars from Eastern Democratic Republic of Congo. *Sustainable Agriculture Research.* 2 :22-23.

Berhanu, T., Melaku , F., Beniam, T., Aberham, K. (2015). Participatory Evaluation of Banana (Musa paradisiaca L var. sapiertum) Production Constraints and Scaling up of Improved Banana Cultivars in Gedeo Zone Southern Ethiopia, *International Journal of Life Sciences.* 4:197-201.

Boshra, V., Tajul, Y. (2013. Tropical Fruits: A New Frontier in the Bakery Indus try. International *Journal of Medical Sciences and Biotechnology.* 1:327-330.

Chtsuda, C., Chockchai, T., Ronalde, W. (2007). Pineapple Juice and Its Fractions in Enzymatic Browning Inhibition of Banana [Musa (AAA Group) Gros Michel], *Journal of Agricultural Food Chemistry.* 55: 4252-4257.

Christiane, Q., Maria, L., Mendes, L., Eliane, F., Vera, L., Valente,M. (2010). Polyphenol Oxidase: Characteristics and Mechanisms of Browning Control, *Food Reviews International.* 24:361 -375.

Christopher, B., Leah, B. (2014). The Micronutrient Deficiencies Challenge in African Food System *Oxford University Press*.123-176.

Charlotte, L.,Melinda, S.(2006). Assessing the social and economic impact of improved banana varieties in east Africa. *Environment and Production Technology Division International Food Policy Research Institute U.S.A.* 56:21-46.

Coulibaly, S., Nemlin, J., Kamenan,A. (2007). Chemical Composition, Nutritive and Energetic Value of Plantain (Musa ssp.) Hybrids CRBP 14, CRBP 39, FHIA 17, FHIA 21 and Orishele Variety. *Journal of Tropicultura* .25:2-6.

Cavalcanti, T., Forster,C., Gomes, A,. Rostagno, M,. Prado, A. (2015). Uses and Applications of Extracts from Natural Sources. *LASEFI/DEA/FEA, School of Food Engineering/UNICAMP University of Campinas, Brazil.* 110:2342-2349.

Chandraju, R,. Mythily, K.,Chidan, K. (2011). Extraction, Isolation and Identification of Sugars from Banana peels (*Musa Sapientum*) by HPLC coupled LC/MS instrument and TLC analysis, *Journal of Chemical Pharm Research.* 3:312-321.

Delia, B., Rodriguez,A.(1997). Carotenoids and Food Preparation: The Retention of Provitamin A Carotenoids in Prepared, Processed, and Stored Foods. *Universidade Estadual de Campinas C.P. Campinas, SP., Brazil.* 45:1325-1331.

Echessa, P.,Nyambaka, H., Ondigi, A.,lice, Omuterema, S.,Toili ,William., Afihini ,M,. Ijaniand, A.(2013). Evaluation of micronutrients in seeds of Pumpkin varieties grown by smallholder farmers in the Lake Victoria Basin, *African Journal of Food Science and Technology*.4:221-228.

Esheteu, B.,Ferdu, A.Tsedeke, A.(2003). Facilitating the Implementation and Adoption of Integrated Pest Management (IPM) in Ethiopia. *Planning Workshop13-15 Melkassa Agricultural Research Center, EARO.* 9:33-37.

Estela, G., Yordi1, E., Molina, P.,Maria, J., Matos, E., Uriarte, V.(2012). Antioxidant and Pro-Oxidant Effects of Polyphenolic Compounds and Structure-Activity Relationship Evidence. *Nutrition, Well-Being and Health.* 124:23-45.

Fungo, R., Kikafunda, J., Pillay,M. (2015). ß-Carotene, iron and zinc content in Papua New Guinea and east African highland banana. *African journal of food agriculture nutrition and development.* 10: 6-8.

Fungo, R. Kikafunda,P. (2010). Variation of ß-carotene, iron and zincin bananas grown in east Africa *African Crop Science Conference Proceedings*. 8: 2117-2126.

Garima, M., Anand, M., Shukla, R. N. (2014). Development of pulse, banana and pineapple pomace based weaning food and its quality evaluation during storage. (2014). *International Journal of Development Research.* 4:1257-1262.

Gnansounou, M., Noudogbessi, P., Yehouenou, B., Gbaguidi, M., Dovonon, L., Aina, P., Ahissou, H. Sohounhloue, D. (2014). Proximate composition and micronutrient potentials of *Dialium guineense* wild growing in Benin. *International Food Research Journal*. 21: 1603-1607.

Haftom ,Z., Geremew, B., Solomon, A. (2015). Physico-chemical and Sensory Properties of Banana Flour-Sesame Paste Blends, *International Journal of Scientific and Research Publications*. 5:2250-3153.

Happi, E., Bindelle , A.,Buldgen,W.,Paquot,M(2010). Ripening influences banana and plantain peels composition and energy content, *University of Liège, Gembloux Agro-Bio Tech, Animal Science Unit*, 21:230-233.

Halit, D., Çilem, Ç., Fatih, Ç. (2012). Purification and characterization of polyphenol oxidase enzyme from Iğdır apricot (Prunus armeniaca L.). *Bitlis Eren University Journal of Science and Technology*. 2:22-26.

Helen, N., Ayo, O., Regina, O. (2013). Assessment of Chemical, Rheological and Sensory Properties of Fermented Maize-Cardaba Banana Complementary Food, *Food and Nutrition Sciences*.4:844-850.

Howarth, B., Bonnie, l. (2007). The Bio Fortification Challenge Program 2006. *Annual Report for the Executive Council of the CGIAR Harvest Plus Program*.35:47-52.

Itelima, F., Onwuliri, E., Onwuliri, I., Oforji, S. (2013). Bio-Ethanol Production from Banana, Plantain and Pineapple Peels by Simultaneous Saccharification and Fermentation Process, *International Journal of Environmental Science and Development*. 4:213: 216.

Jan, M., María, G., María, P., Martín, L., Milan, Ž., Julián, C., Rivas, G. (2007). Measurement of Antioxidant Activity of Wine Catechins, Procyanidins, Anthocyanins and Pyranoanthocyanins, *International Journal of Molecular Science*. 8:797-809.

Jerry James M. de la Torre. (2009). Effect of frequency on polyphenol oxidase activity during moderate electric field treatment, *Ohio State University*. 1:4-51.

Jin, D., Russell, J., Mumper, (2010). Plant Phenolic: Extraction, Analysis and Their Antioxidant and Anticancer Properties, Molecules, *International Journal of Molecular Science*. 15: 7313-7352.

Jouni, K. (2011). Measurement of Carotenoids and Their Role in Lipid Oxidation and Cancer Institute of Public Health and Clinical Nutrition Institute of Clinical Medicine, *Department of Clinical Chemistry Faculty of Health Sciences, School of Medicine University of Eastern Finland Kuopio*. 548:1276-1288.

Kamalpreet, K.,Uma, S., Shivhar.E,. Santanu, B., G. S.Vijaya, R .(2013). Kinetics of Extraction of β-Carotene from Tray Dried Carrots by Using Supercritical Fluid Extraction Technique. *Food and Nutrition Sciences*. 3:591-595.

Kalagbor, A., Naifa, B., Umeh, N. (2014). Analysis of Heavy Metals in Four Fruits from Sii and Zaakpon Communities in Khana, Rivers State International, *Journal of Emerging Technology and Advanced Engineering*. 4:23-25.

Kayshar1, M., Rahman, A., Sultana, M., Fatema, H., Kabir, F. (2014). Formulation, Preparation and Storage Potentiality Study of Mixed Squashes from Papaya, Banana and Carrot in Bangladesh, *IOSR Journal of Agriculture and Veterinary Science*. 7: 47-51.

Kahsay, B.Ranjitha, P.,Worku, T., Dirk, H.,Azage, T.(2014).Innovation in banana value chain development in Metema district, North-western Ethiopia: *IPMS experiences*. 26-27.

Kamal,A., Mohammed, A., Gasmalla, H. (2015). Efficient Methods for Polyphenol Oxidase Production, *International Journal of Nutrition and Food Sciences*. 4: 656-659.

Khandker, A., Khairul, I., Jamal, H., Nure, A., Kazi., Faisal, H. (2012). Status of the behavioral pattern of biochemical properties of banana in the storage condition, *International Journal of Biosciences*. 2: 83-94.

Katie, M., Kelly, W., Ashley, F., Ellen, S., Kestas, B., (2008). Comparison of Biochemical and Chemical Digestion and Detection Methods for Carbohydrates, *American Journal of understanding research*. 7:7-18.

Kayshar1, M., Rahman, A., Sultana, M., Fatema, K., Kabir, M. (2011). Formulation, Preparation and Storage Potentiality Study of Mixed Squashes from Papaya, Banana and Carrot in Bangladesh, *Journal of Agriculture and Veterinary Science*.7: 47-51.

Liyong, C., Ruiping, L., Chengyong, Q., Yan, M., Jie, Z,.Yun, W., Guifa, X. (2010). Sources and intake of resistant starch in the Chinese diet, *Asia Pacific Journal of Clinical Nutrition*. 19:274-282.

Le, P.,Tan, Q.,Truong, H. (2015). Effect of Nopal Gel Solution on the Preservation of Banana (Musa Paradisiaca), *Agricultural and Biological Sciences Journal*. 3:95-99.

Lois, E.,Ian,D.,Hill, T. C.,Maureen, H. F.,Geoffrey, C. M.(2003). Carotenoid-rich bananas: A potential food source for alleviating vitamin A deficiency. *The United Nations University, Food and Nutrition Bulletin*. 4-5.

Lois, E., Joseph, S., Geoffrey, C., Marks., Maureen, F. (2003). Micronesian banana, taro, and other foods: newly recognized sources of pro-vitamin A and other carotenoids, *Journal of Food Composition and Analysis*. 16: 3–19.

Marisa, M. (2006). Wall Ascorbic acid, vitamin A, and mineral composition of banana (Musa sp.) and papaya (*Carica papaya*) cultivars grown in Hawaii, *Journal of Food Composition and Analysis*. 19:434–445.

Mahya, S., Vahid, H., Mohammad, R. A. (2015). Carotenoids Extraction Optimization of Lutein-Based Banana Peel. *Journal of Applied Environmental and Biological Science*. 4: 213-217.

Makanjuola, O., Ajayi, A., Bolade, M., Makanjuola, J. (2013). The proximate composition and mineral contents of three plantain cultivars harvested at matured green level, *International Journal of Innovations in Bio-Sciences*. 3: 23-26.

Maina, H, Heidi, E., Shagal, M. (2012). Analytical screening of nutritional and non-essential components in unripe and ripe fruits of banana (*Musa sapientum*), *International Journal of Medicinal Plant Research*. 1:1020-1025.

Markus, F., Elena, R., Rodríguez, J., Darias, M.,Carlos, D. (2013). Distribution of Nutrients in Edible Banana Pulp, Food Technol. *Journal of Biotechnology*. 41:167-171.

Mohebbi, M., Shahidi, F., Fathi,, M., Ehtiati,A., Noshad, M. (2011). Prediction of moisture content in pre-osmosed and ultrasounded dried banana using genetic algorithm and neural network, *Journal of food and bio-products processing.* 8 9:362–366.

Mmeka,M., Ebelechukwu , A., Adenubi, V., Bi I,K.(2013). Single nucleotide polymorphism (SNP) markers discovery within Musa spp. (plantain landraces, AAB genome) for use in beta carotene (Provitamin A) trait mapping, *American Journal of Biology and Life Sciences.* 1: 11-19.

Maisarah, A., Asmah, R., Fauziah, O. (2009). Proximate Analysis, Antioxidant and Anti-Proliferative Activities of Different Parts of Carica Papaya, *Journal of Nutrition and Food Science.* 4:2.

Matook, S., Mokbel, V., Fumio, H. (2013). Antibacterial and Antioxidant Activities of Banana (Musa, AAA cv. Cavendish) Fruits Peel, *American Journal of Biochemistry and Biotechnology.* 1: 125-131.

Meng, L., David, C., Slaughter, J. (1997). Optical chlorophyll sensing system for banana ripening. Optical chlorophyll sensing system for banana ripening, *African Journal of Agriculture.* 2: 273–283.

Moreiral, A.,Fageria, K. (2009). Yield, Uptake, and Re-translocation of Nutrients in Banana Plants Cultivated in Upland Soil of Central Amazonian, *Journal of Plant Nutrition.* 32: 443–457.

Nednapis, V., Boonma, N., Karuna, W. (2012). Resistant starch content, in vitro starch digestibility and physico-chemical properties of flour and starch from Thai bananas. *Maejo Interenational Journal of Science and Technolgy.* 6:259-271.

Nweze, C., Ombs, S., Uzoukwu ,E.(2015). Effects of evaluation of three local processing methods on the dietary mineral element content of *Mussa paradisiacal. International Journal of Science, Environment and Technology.* 4: 64 – 72.

Nuratiah.,B. (2010) . Extraction of antioxidant activity, phenolic contents minerals in banana peel. *Faculty of Chemical & Natural Resources Engineering University Malaysia Pahang.* 678-689.

Norbert, C,. Furumo,Z,. Sheldon, F. (2015). A Simple Method for Assaying Total Protein, Polyphenol Oxidase and Peroxidase Activity from 'Kaimana' Litchi chinensis Sonn, *Journal of Hawaiian and Pacific Agriculture.* 67:1232-1245.

Qiang, H., Yaguang, L., Pei, C. (2008). Elucidation of the mechanism of enzymatic browning inhibition by sodium chlorite, *Journal of Food Chemistry.* 110: 847–851.

Okorie, D., Eleazu, N. (2015). Nutrient and Heavy Metal Composition of Plantain (*Musa paradisiaca*) and Banana (*Musa paradisiaca*) Peels, *Journal of Nutrition and Food Science.* 5:3.

Qiang, H., Yaguang, L., Pei, C. (2008). Elucidation of the mechanism of enzymatic browning inhibition by sodium chlorite, *Journal of Food Chemistry.* 110:847–851.

Pallavi, J,. Kanika, V. (2015). Assessment of Nutritional and Physiochemical properties of Banana Flour, *Research Journal of Family, Community and Consumer Sciences.* 3:1-3.

Phebe, D.,Yap, S. (2014). Browning assessment methods and polyphenol oxidase in UV-C irradiated Berangan banana fruit, *International Food Research Journal.* 21: 1667-1674.

Poon, G. (2012). Determination and comparison of non-enzymatic antioxidants from different local varieties of banana (Muss asp.). *International Journal of Pharmacy and Biological Science*.3:17 – 24.

Priti, G., Jaswant, R., Bipin, A., Pankaj, G. (2015). Food Processing Residue Analysis and its Functional Components as Related to Human Health: Recent Developments. *Austin Journal of Nutrition and Food Sciences*. 24:76-82.

Ramakrishnan, B., Selvaraj, S., Babu, S., Radhakrishnan, S., Radhakrishnan, N., Palanisamy, P. (2011). Antioxidant Potential of Peel Extracts of Banana Varieties (*Musa sapientum*), *Food and Nutrition Sciences*. 2:1128-1133.

Ricardo, K., Oia,B., José, C., Santanac, C.,Elias, B,. Tambourgi, B., Moraes, J. (2013). Feasibility Study for Production of Green Banana Flour in a Spray Dryer, *The Italian Association of Chemical Engineering*. 32:1825-1832.

Rushikesh, P., Kailash, C. (2014). Study on Effect of Pretreatments and Microwave Drying On Banana Chips, *Journal of Agriculture and Veterinary Science*. 7:4-10.

Robert, F.,Michael, P. (2011). β -Carotene content of selected banana genotypes from Uganda African *Journal of Biotechnology*. 10: 5423-5430.

Roberto, Q., Oscar, D., Betty, R., Franco, P., Miguel, A. (2009). Description of the kinetic enzymatic browning in banana (Musa Cavendish) slices using non-uniform color information from digital images, *Food Research International*. 42:1309–1314.

Róa. B., Janusz, (2007). The effect of selected compounds as inhibitors of enzymatic browning and softening of minimally processed apples, *Journal of Biotechnology*. 6:37-49.

Randy, P., Angela,K., Jeff, D.,Scot,N.(2013). Banana and plantain—an overview with emphasis on Pacific island cultivars, *Journal of Biotechnology*. 12:2754-2761.

Sanjeev, K., Chanchal, K.,Mishra, A.,Asha, R.(2012). Phytoconstituents and Pharmacological activities of *Musa paradisiaca* Linn. *Asian Journal of Biochemical and Pharmaceutical Research*. 4:11-13.

Staffan C., Carotenoids, T. (2009). Chlorophylls in Sea Buckthorn Berries (*Hippophae rhamnoides*) and Rose Hips (Rosasp). *Swedish University of Agricultural Sciences Alnarp*. 9:962-966.

Suparm, H., Prasetya, M., Martosupono, L.,Tri, S. (2014). Effect of β-Carotene from Yellow Ambon Banana Peel on Rat Serum Retinol Level. *Journal of Pure Applied Chemistry Research*. 3:83-88.

Sajib, M.,Jahan, S., Islam, Z., Khan, A., Saha, K.(2014). Nutritional evaluation and heavy metals content of selected tropical fruits in Bangladesh. *International Food Research Journal*. 21: 609-615.

Senayit, Y., Tiruset, H. (1994) Evaluation and utilization studies of horticultural crops. In: *Edward H, Lemma D (eds) Horticulture research and development in Ethiopia. IAR and FAO, Addis Ababa*. 301–309.

Selvamani. P., Manivannan, K., Jagan, M. (2009). Proximate Composition and Pasting Behavior of Starch from Indian Bananas (Musa Spp), *Botany Research International*. 2: 103-106.

Seifu G. (2003). Status of commercial fruit production in Ethiopia. *Ethiopian Agricultural Research Organization.*

Sheryl, L., Sadili, B., Maria, F., Raposo, R., Alcina, M. (2010). Chemical dips and edible coatings to retard softening and browning of fresh-cut banana. *International Journals of Postharvest Technology and Innovation.* 2:21-14.

Shyamala, B., Nagarajaiah, s., Jamuna, P. (2011). Chemical composition and antioxidant potential of peels from three varieties of banana, *Asian Journal of Food and Agricultural Industries*. 4:31-46.

Solange, C., Célio, W., Pedro, O., Cristiana, S. (2013). Enzyme from Banana (Musa sp.) Extraction Procedures for Sensitive Adrenaline Biosensor Construction, *American Journal of Analytical Chemistry.* 4:293-300.

Sogo, T., Idowu, O., Idowu, E. (2014). Effect of Biological and Chemical Ripening Agents on the Nutritional and Metal Composition of Banana (Musa spp), *Journal of Applied Science and Environmental Managements.* 18:243-246.

Sohail, A., Rab, N., Fayaz, Zulfiqar, A. (2015). Study on Growth Effects of Major Nutrients. Composition to Banana Cultivation in Coastal Areas of Sindh, Pakistan, *American Journal of Plant Sciences.* 6:1003-1010.

Subhashree,B., Moumita,D.,Anurupa, S.,Utpal,R., Gouriprosad,D.(2014).At Bengal, India. Analysis of complete nutritional profile of *Amorphophallus campanulatus* tuber cultivated in howrah district of west *Asian Journal of Pharmacology and Clinical Research.* 7 :25-29.

Sule, S., Efe, U., Afolabi ,A., Aline, A., Boligonand, M.,Athayde,L.(2015). Antioxidant potential, phenolic profile and nutrient composition of flesh and peels from Nigerian white and purple skinned sweet potato (*Ipomea batatas* L.). *Asian Journal of Plant Science and Research.* 5:14-23.

Tapre, A,. Jain, R. (2012). Study of advanced maturity stages of banana, *International Journal of Advanced Engineering Research and Studies.* 1: 272-274.

Teshome, B. (2012). Perennial Based Cropping Pattern in the Western Hills of Lake Abaya, Gamo Highland, Ethiopia. *Agricultural Science Research Journals.* 2:561- 567.

Tsegaye, D.,Ahmed, A.,Dilnesaw ,Z.(2009). Availability and consumption of fruits and vegetables in nineregions of Ethiopia with special emphasis to vitamin A deficiency. *Ethiopian Journal of Health Development.* 23:23-27.

Tekle, Y., Wondewosen, S.,Zemach, S.,Tibebu, S.,Abraham, S.,Woineshet, S. (2014). Adaptability study of banana (Musa paradisiacal var. sapiertum) varieties at Jinka, southern Ethiopia. American *Journal of Agriculture and Forestry.* 2: 250-255.

Tesfaye, A. (2013). Determinants of crop diversity and composition in Enset-coffee agroforestry home gardens of Southern Ethiopia. *Journal of Agriculture and Rural Development in the Tropics and Subtropics.* 114:29–38.

Theji, M., Rajesh, P., Fathimathu, Z., Vijitha, K. (2014). Magnitude of Changes in the Activity of Amylases and Cellulase and its Association with the Biochemical Composition during Maturation and Ripening of Banana (Musa spp.). *Journal of Biochemistry and Physiology*. 3:2.

Tan, S., Aminah, A., Khalid, H., Musa, M., Yusof,M., Maaruf, A. (2012). Antioxidant Properties of Three Banana Cultivars (*Musa acuminata* 'Berangan', 'Mas' and 'Raja') Extracts, *Sains Malaysiana Journal*. 41:319–324.

Tekle, Y., Wondewosen, S., Zemach, S., Tibebu, S., Woineshet, S., Abraham, S. (2014). Adaptability study of banana (*Musa paradisiacal*) sapiertum varieties at Jinka, southern Ethiopia, *American Journal of Agriculture and Forestry*. 2: 250-255.

Tigist, M., Workneh, T., Woldetsadik, K. (2011). Effects of variety on the quality of tomato stored under ambient conditions. *Journal of Food Science Technology*. 10:111-178.

Tom, O. (2007). Banana Research and Development in the Pacific Status Report 2002INIBAP/ BAPNET. *Agriculture Adviser Secretariat of the Pacific Community Suva, Fiji*. 677-689.

Victor, M., Luiz, C., Chamhum, S., Dalmo, L., Ignacio, A., Leonardo, C., Brant,M. (2008). Physical and metabolic changes induced by mechanical damage in 'dwarf-prata' banana fruits kept under cold storage, *African Journal of Computational Science*. 8:1029-1037.

Wamono, K., Kaaya, N., Ng'ang'a, Z., Wamue, G., Manyama,A., Mwangi, M.(2011).Nutrient enhancement of matooke banana for improved nutrient intake of people living with HIV/AIDS in rakai district, Uganda. *African Journal of Food Science and Technology*. 11: 4-7.

Workneh, T., Osthoff, G., Steyn, M. (2011). Effects of pre-harvest treatment, disinfections and storage environment on quality of tomato. *Journal of Food Science and Technology*. 10:197-221.

Zomol, S., Ismail, S., Shah, Jahan., Kabir, K. (2014). Chemical Properties and Shelf Life of Banana (Musa sapientum L.) as Influenced by Different Postharvest Treatments, *A Scientific Journal of Krishi Foundation*. 12: 6-17.

Zhan-Wu, S., Wei-Hong, M., Jin-He, G., Yang, B., Wei-Min, Z., Hua-Ting, D., Zhi-Qiang, J. (2011). Antioxidant properties of banana flower of two cultivars in China using 2,2-diphenyl-1-picrylhydrazyl (DPPH,) reducing power, 2,2'-azinobis-(3-ethylbenzthiazoline-6- sulphonate (ABTS) and inhibition of lipid peroxidation assays, *African Journal of Biotechnology*. 10:4470-4477.