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Development of Dried fruits from indigenous wild edible fruit *mimusops kummel* by using hot thin layer dryer

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Abstract

The study was conducted with the aim of development dried fruit from indigenous fruit mimusops kummel by using hot thin layer dryer. Products can be consumed as snack and it be can be used as an ingredient for different types of food. . The proximate composition of fresh and dried mimusops kummel was (protein 2.54±0.05 and 2.49±0.13, *crude fat 1.4*±0.04 and 1.26±0.12, *crude fiber 9.87±0.03, moisture content 64±1.7and 19.36±0.6 and carbohydrate 29.29±0.197and 73.96±3.44) respectively. The drying were performed drying temperature (55, 60 and 65^{O}C), drying air volumetric flow rate (1 and 2 m^3/sec) and drying time (4 and 5hr) respectively the experiment were done the drying temperature (55, 60 and 65 ^{o}C) drying air volumetric flow rate (1and 2m^3/s) and drying time (4 and 5hr), Color of fruit was measured by using chroma meter (LAB method) L, 46.39±2.88 A, 29.28±4.50 and B, 44.08±4.08 respectively. The amount of vitamin c (ascorbic acid) in fresh and dried fruit was 14.48±0.8 and 12.45mg/100g respectively. The amount phytochemicals in the dried mimusops kummel was determined 46.45±2.02 mg/100g flavonoid, saponins 6000.00±2.00 mg/g, tannin 294.20±0.55 mg/100g, total phenol 57.46±1.015 mg/100g, oxalate 18.90*±0.30 *mg/g and phytate 104.74±2.18mg/100g respectively. Result of Iron, 150.10±5.9, Sodium 17.20±0.60 potassium 36.6±1.40, 81.4±0.60 and Zinc 25.4 ±1.60 mg/100g respectively. Sensory characteristics of dried mimusops kummel (texture, color, taste, appearance and overall acceptability) were also studied to evaluate the acceptability of the product. The sensory results indicated that the product produced with a temperature of 55^{0}C, and air flow rate of 1m^3/s was supposed as the most accepted product, as compared to the other product drying with different drying parameters the higher air temperature and volumetric flow rate indicated the lower drying time. The sensory results indicated that the product produced with a temperature of 55^{0}C, and drying air volumetric flow rate of 1m^3/sec and drying time 4 hr was perceived as the most accepted product, as compared to the other products fruit processing*

Keywords: *Mimusps kummel, Wild edible fruit, Hot thin layer drier, Dried mimusops kummel*

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List of Abbreviations

ANOVA	Analysis Of Variance
AOAE	Association of Official Analytical Chemist
CFU	Colony Forming Unit
CSA	Central Statistics Authority
CVD	Cardiovascular Ddiseases
EPHI	Ethiopian Public Health Institute
FAO	Food and Agricultural Organization of the united nation
MMA	Match Marker and Associate Limited
NTPs	Non Timber Products
RNI	Recommended Nutrient Intake
RNS	Reactive Nitrogen Species
ROS	Reactive Oxygen Species
SD	Standard Deviation
TFTC	Too Few To Count
NCD	Non Communicable Diseases
UNIDO	United Nations Industrial Development Organization
WEP	Wild Edible Plants
WHO	World Health Organization

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CHAPTER ONE

Introduction

1.1 Background

Thousands of species of wild fruits are consumed worldwide. Fruits are especially good sources of minerals and vitamins and sometimes contribute significant quantities of calories. Fruit is most commonly consumed raw, as a snack or dietary supplement. Forest fruits are also widely used for making beverages, most notably beer (FAO, 2011).

Millions of people in many developing countries have shortages of food to meet their daily requirements and a further more people are undersupplied by different micronutrients (Ross m Welch and Robin D.Graham, 1999). Most rural communities depend on wild resources including wild edible plants to meet their food needs in different food crisis. Due to the diversity in wild species they have their own role in contribution to food source and household food security (FAO, 2004 and Balemi and Kebebew, 2006).

In Ethiopia, there are about 370 indigenous food plants (belonging to 70 different families) out of which 182 species (40 families) are shrubs/trees with edible fruits/seeds (Neela, 2015). Out of those 25 marketable fruits/seeds, 21 are marketable in local markets, 2 are reported national (Mimusops kummel and Ziziphus spina-christi) (Bashir Awad El Tahir, 2006). The name of the genus Mimusops comes from Greek words mimo meaning ape and ops meaning resembling (Palmer and Pitman, 1972). Mimusops kummel belongs to Kingdom - Planate; Phylum - Magnoliophyta; Class - Magnoliopsida; Order - Ericales; Family - Sapotaceae and Genus - Mimusops. The genus Mimusops as described by Linnaeus in 1753 contained 57 species that are widespread throughout the tropical, subtropical and various oceanic islands areas of the world up to 2,100 m altitude (Alain et al., 2013).

Mimusops kummel is a deciduous tree small-to medium-sized tree up to (25 -35) m high, containing latex; bole up to 100 cm in diameter; bark deeply grooved, dark grey; crown dense, ovoid; young densely red-brown pubescent branches. Its fruit is an ellipsoid to ovoid berry up to 2.5 cm long, orange-red when ripe, containing a single large seed. The fruits taste pleasant and are used for making juice and alcoholic drinks. Mimusops kummel is commonly found in secondary forests, around lakes, in moist or dry evergreen upland forests and woodlands.

Mimusops kummel, which is depicted below, is native to Guinea, Cote D'Ivoire, Eritrea, Ethiopia, Kenya, Uganda, Tanzania and Malawi (Alain et al., 2013). Mimusops kummel fruits are principally used in Ethiopia for treatment of diarrhea as well as in the treatment of amoeba (eating fruits) (Teklehaymanot and Giday, 2007).

Drying is one of the oldest methods of preserving food. It is a process in which moisture is removed from a solid using heat as the energy input. Drying is a common unit operation in food processing facilities to lower the moisture content of foods in order to reduce water activity and prevent spoilage or reduce the weight and the volume of food products for transport and storage. In many agricultural countries large quantities of food products are dried to improve shelf life, reduce packaging costs, lower shipping weights, enhance appearance, retain original flavor and maintain nutritional value of fial product (Sokhansanj, and Jayas, 2006).

Numerous European populations have centuries-long traditions of using dried fruits, vegetables and herbs in traditional home diet, implementing mostly the natural convective method (http://dieti.net/susheni-plodove, Dried fruits and vegetables,2011). This method is particularly popular on the Balkans where there are beneficial climatic conditions for cultivation of various fruit varieties. Fresh fruits and vegetables are perishable. They contain significant amounts of water that is a favorable medium for development of microorganisms and for the progress of certain biochemical processes affected by various enzymes (ferments). Thus the products perish quickly. In order to achieve their stability the water contained in them should be reduced to a certain minimum limit. For dried fruits this value should be from 18 to 23% and for vegetables –from 8 to 12%. The elimination of a substantial portion of water allows the fruits and vegetables to decrease their volume and weight and transform into a "concentrated product", thus enabling their storage in ordinary conditions(Gyurova et al., 2014)

1.2 Statement of Problem

Ethiopia import different types of flavor (ingredients) use for an input for food processing industries this leads to high foreign currency for the country. However it has a lot of potential to manufacture and export dried fruits to end hard currency.

The Food and Agriculture Organization (FAO) for instance is aware of the fact that wild foods are significant for global food security (FAO, 2009). However, studies addressing the contribution of WEPs and biodiversity to human diets are still rare and there are huge deficits with respect to information on WEPs nutritional properties.

Non communicable deaseas (NCD) s such as cardiovascular diseases (CVD), cancer and chronic respiratory diseases are among the major health problem in the world. The contribution of this disease to mortality, and morbidity is projected to increase tremendously by the year 2030 (Misganaw*et al*., 2014).

Many literature sources show that fruits and vegetables contain natural compounds such as; carotenoids and phenolics those are envisioned to have significant antioxidant activity and can help in preventing NCDs. Although there are numerous study findings on nutritional composition and antioxidant properties of fruits and vegetables, According (Demel &Abeje, 2002) there no information available on the nutritional value of mimusops kummel fruit in Ethiopia.

The most common micronutrient deficiencies in women are iron, vitamin A, iodine, folate and zinc (Muthayya., et al, 2013). It is well known that iron deficiency has adverse effects on productivity and cognition in the general population and is the leading cause of anemia during pregnancy, contributing to 20% of all maternal and perinatal mortality and low birth weight (Darnton et al., 2005).

1.3 Objectives

1.3.1 General objective

The general objective of this study was development of dried fruit from Ethiopian indigenous wild edible fruit *mimusops kummel (Ishe).*

1.3.2 Specific objectives

- Evaluate the effects of drying temperature, time and volumetric flow rate using hot thin layer dryer drying process.
- Analyze proximate composition and minerals of mimusops *kummel fruit.*
- Optimize the drying parameters (air flow rate, temperature and time) to process the product.
- Evaluate phytochemical fruits (flavonoid, phytate, tannin, oxalate total phenol and saponnin) in *mimusops kummel.*
- Asses the microbial quality of *mimusops kummel* fruit final products.
- Evaluate sensory attributes of the dried fruit develop from *mimusops kummel* fruits.

1.4 Significance of study

The development, promotion, and wider utilization of wild edible fruit particularly in the dry land areas undoubtedly resolve the food insecurity problems. Wild edible fruit immensely contribute to family household food security and serve as means of survival during times of drought, famine, shocks and risks. They can also supplement nutritional requirements due to their better nutrition.

Ethiopia is one of the country rich in wild edible fruit as some literature indicate most of the time fruits are consumed as raw in rural area but it is not practice in the central area of the country. So, this study will focused on the development of dried fruit from Ethiopian indigenous wild edible fruit (Mimusops kummel) and give direction about utilization of wild edible fruits by producing value added products and how utilize this types of fruit and reduce post-harvest loss of fruits and enhance income generation and provide employment opportunity in the country. This study also reduces the foreign currency.

CHAPTER TWO

2. Literature review

In Ethiopia, there are lots of food materials that are obtained from plants. According to(Asfaw and Tadesse ,2001) 8% of the higher plant species in the country are edible, and 25% of these are cultivated and there are also many wild edible plants that produce quantities of food(Atinafu et al.,2017) .More than 80% of the populations in Ethiopia are residing in rural areas. These rural people preserve some of the more important indigenous species by either domesticating them on their farms and home gardens or by preserving and managing them (Guinand, and Dechassa, 2000). Indigenous fruits play a vital role in the livelihoods of many communities in the region. They are collected by local communities to supplement their diet particularly during famine or in the event of natural disasters. Wild fruits contain vital nutrients (carbohydrates, protein, and minerals) and essential vitamins, which are important especially for the growing children who are prone to malnutrition and related diseases. Some of the fruits have become articles of commerce in the local, national and international markets thereby contributing to local and national incomes (Joke and Erdey, 2003).

2.1. Overview of wild edible fruit in Ethiopia

Indigenous fruits play a vital role in the livelihoods of many communities in the region. They are collected by local communities to supplement their diet particularly during famine or in the event of natural disasters. Wild fruits contain vital nutrients carbohydrates, protein, minerals and essential vitamins, which are important especially for the growing children who are prone to malnutrition and related diseases. Some of the fruits have become articles of commerce in the local, national and international markets thereby contributing to local and national incomes. Ethiopia has not only diverse flora and fauna but also rich indigenous knowledge on both domesticated and wild plants. The use of wild plants in the native diet, traditional medicine and religious ceremonies is widespread. Wild food plants are those plants with edible parts, namely leaves, fruits/seeds, roots and tubers, gums and saps, bark as well as pollen and nectar for honey production (by bees), that are found growing naturally without having been purposely cultivated (Demel &Abeje, 2002).

Ethiopia is an agrarian country and agriculture, including forestry, accounts for 54% of the Gross Domestic Product, employing about 80% of the population, accounts for about 90% of the exports and supplies over 90% of the raw materials for the agro-industries (CSA, 2001). The country has a huge resource base, which with the potential to improve agricultural productivity (Teketay, 2004).

2.2 Importance and traditional knowledge on wild indigenous fruits

Ethiopia has not only diverse flora and fauna but also rich indigenous knowledge on both domesticated and wild plants. Besides being sources of wood for various purposes and other forms of non-wood/timber products (NTPs), the use of wild plants in the native diet, traditional medicine and religious ceremonies is wide spread. Wild food plants are those plants with edible parts that are found growing naturally without having been purposely cultivated (Katende *et al*., 1999).Fruits are a seasonal food supply and are often eaten as snacks. All of these types of food provide essential elements in the human diet. They also provide a number of important dietary elements that the normal agricultural produce does not adequately provide. In many areas, dietary deficiencies and monotony of normal diets are reduced or avoided, through this “hidden harvest” (Pol, 2002).

The relevance of wild fruit and the need to introduce more plant foods in order to bridge the gap of alarming food shortage in human nutrition have aroused attention of researchers thought out the world especially in developing country .wild fruits are gaining increased attention as potential food supplement or cheaper alternative of domesticated exotic fruits across the world. The role played by wild fruits in food security and economy welfare of rural community in developing countries cannot be over emphasized (John et al., 2016).

2.3 Edible wild plants in food security and nutrition

Edible wild plants play a critical role in insuring food and livelihood security for countless families and communities around the world. They are parts of diet of farm households on a daily basis not just during periods of food shortage and also provide a number of important dietary elements that normal agricultural produce does not adequately provides. Edible wild plants may have higher fat, proteins, minerals and vitamins contents than cultivated species. For instance fruits provide vitamins and minerals particularly Vitamin A and C, Zinc, Iron, Iodine, Thaimine, Riboflavin and Folacin (Ohiok, 2003).

According to (FAO 2004 and Maghembe et al,. 1994) the nutritional value of indigenous fruit bearing tree species indicate that many are rich in energy sources (sugars), essential vitamins and minerals while others are high in vegetable oil and proteins.

The contribution of WEPs to the total micronutrient intake is rather marginal and ranges from 0% to 8%, depending on the nutrient. Cupper represents an exception. The cupper intake from WEPs accounts for 55% of the total usual daily cupper intake. This can mainly be explained by the consumption of the green leafy vegetables *Vitex doniana* (61.75 mg cupper/100 g cooked product) and *Celosia argentea* (34.95 mg cupper/100 g cooked product) and the frequent consumption of soumbala (5.1 mg cupper/100 g). Vitamin C from WEPs has a share of 8%. This is interesting seeing that 36% of the women have vitamin C intakes below the RNI. The iron intake from WEPs accounts for 6% of the total iron intake. Also with regard to the iron intake, there is a share of women below the RNI (10%). As 61% of the respondents have a calcium intake below the RNI, the WEP contribution of 5% to the total calcium intake can be interesting as well. For thiamine and riboflavin WEPs have a share of around 5%. Thus, the riboflavin intake from WEPs can also play a role as 40% of the respondents have riboflavin values below the RNI (Julia, 2013).

2.4 Phytochemicals in wild edible fruit

Fruits and vegetables, containing abundant dietary fiber, vitamins, and minerals, in particular large amounts of phytochemicals are recommended by nutritionists because of their health benefits(Baliga et al., 2011& Deng et al.,2013) Phytochemicals in these natural products are considered to be responsible for positive health outcomes. Wild fruits are fruits of wild plants, and are often exotic, underutilized, or less known. Many wild fruits are safe to consume, and some have been developed as medicines. Due to different genotypes and environmental concerns, wild fruits contain rich phytochemicals such as anthocyanin and flavonoids. Therefore, wild fruits are often considered to be healthy foods. In recent years, wild fruits have attracted increasing attention, and accumulative investigations have been performed for their bioactive effects, such as antioxidant, antimicrobial anti-inflammatory, and anticancer effects. These studies pointed out that wild fruits could have the potential to prevent and treat some chronic diseases. This review summarizes the bioactivities and health benefits of wild fruits. (Giampieri et al., 2014).

2.4.1 Bio and antioxidant activity of wild fruits

Free radicals are normally produced as a byproduct of cellular metabolism. Free radicals are capable of killing bacteria, damaging biomolecules, provoking immune responses, activating oncogenes, causing atherogenesis, and enhancing the ageing process. The most important classes of radical species generated in living systems are reactive oxygen and nitrogen species (ROS and RNS). The excessive production of ROS and RNS could play a pivotal part in many human chronic diseases, including atherosclerosis, diabetes mellitus, cancer, rheumatoid arthritis, cataract, and Parkinson's disease (Ansari 1997). Various natural products have been proved to have antioxidant activities, such as fruits, vegetables, edible flowers, cereal grains, wine, herbal plants, and their tea infusions. Therefore, natural resources of antioxidants have been considered as quite important. There have been several experiments both in vivo and in vitro proving that many wild fruits possess antioxidant activities, such as wild blueberries, wild apples, and wild hawthorn fruits (Ya Li et al., 2016).

2.5 Marketed indigenous fruits

The indigenous fruits, which are sold in the market included:

(i) **Northern Ethiopia:** *Adansonia digitata, Balanites aegyptiaca, Carissa spinarum, Cordia africana, Dovyalis abyssinica, Mimusops kummel, Rosa abyssinica, Syzygium guineense, Tamarindus indica, Ximenia americana* and *Ziziphus spina-christi*; and unidentified species with local names: 'Serkin' (Amharinya);

(ii) **Southwestern Ethiopia:** *Annona senegalensis, Dovyalis abyssinica, Syzygium guineense* and *Ximenia ameicana*; and unidentified species with local names: 'Megato'(Kefinya), 'Butich' and 'Chato' (Shekonya).

(iii) **Eastern Ethiopia:** *Berchemia discolor, Grewia ferruginea, Protea gaguedi* and *Zizyphus mucronata*; and

(iv) **Southeastern Ethiopia:** *Annona senegalensis, Flacourtia indica, Mimusops kummel, Syzygium guineense, Tamarindus indica* and *Ximenia americana*

Some of the fruits were collected and marketed by poor farmers as a source of income. The fruits were sold in the market either in piece/number, e.g. Dovyalis abyssinica, Mimusops kummel and Ximenia americana, or by using a small container, known locally as 'Askatila' for all other edible fruits. Some of the fruits, such as Mimusops kummel and Ziziphus spina-christi, were transported for more than 250 km from the production area to the market area, and fruits of Tamarindus indica and Balanites aegyptiaca are exported to markets in Sudan through local routes. Almost all fruits are preferred by and sold to children except Mimusops kummel, Tamarindus indica, 'Megato' and 'Chato', which are marketed also for their medicinal values. According to the merchants, worms attack some fruits when they are harvested at the wrong period (lately). Some fruits are also perishable when stored for four or more days (Demel and Abeje , 2002).

2.6 Overview of mimusops kummel fruit

Mimusops kummel is locally called Ishe. Food Value and Processing Mostly the fruits are eaten raw, but they are also roasted lightly on a metal pan over the fire for a few minutes. The fruit are sometimes stored for a couple of weeks to ripen and become sweeter. The ripe fruits are directly used as supplementary diet and also during food shortage seasons. No information is available on the nutritional value of fruits. The fruits are eaten to cure high blood pressure the fruits have local and national market prospects, and prospects for agro industrialization, e.g. jams and jellies, and medicine against high blood pressure (Demel and Abeje, 2002).

2.6.1 Flowering and fruiting phenology of mimusops kummel

In Ethiopia and ACD, 60 specimens of *M. kummel*, collected by different botanists/plant collectors between 1960 and 1999 in twelve out of 14 of the Floral Regions of Ethiopia, were found. Study of these specimens revealed variations in the phenophases of the species in the different Floral Regions: (1) AR: flowering in May; (2) BA: (a) vegetative in April, June-August and October; and (b) flowering in June; (3) GG: (a) flowering in March; and (b) fruiting in October; (4) GJ: (a) vegetative in February and September; (b) flowering in January, March and April; and (c) fruiting in January, February and October; (5) GD: (a) flowering in February and November; and (b) fruiting in July and October; (6) HA: (a) flowering in February and June; and (b) fruiting in August and October; (7) IL: (a) vegetative in May and August; (b) flowering in April; and (c) fruiting in December; (8) KF: (a) vegetative in January; (b) flowering in April; and (c) fruiting in August, October - December; (9) SU: (a) vegetative in January; (b) flowering in February and April; and (c) fruiting in February, April, June, October and November; (10) SD: flowering in April and December; (11) TU: fruiting in August; and (12) WG: (a) flowering in

February, April and May; and (b) fruiting in August, October and November (Demel *et al*., in preparation).

2.6.2 Local name mimusops kummel fruit in different area of Ethiopia

Table 2.1 *Local name mimusops kummel fruit in different area of Ethiopia*

Different area of Ethiopia	**Local names**
Amharinya	Ishe, Isheh, Iskyeh, Kummel, Safa, She, Sheh, Shi, Shio, Skyh
Anuwakinya	Achak, Ashak, Atchak
Kefinya	Loko, Gayu
Majenger	Woni/Wonni
Orominya	Bururu, Bururi/Buruurii, Butugi, Dambii, Dembi, Koladi, Kolati/Kolatti, Konch, Koncho, Konjo, Mito/Mitto, Mixoo, Naga-qadadii, Nagak-adadi, Nega-kadadi, Olati, Qolaadii, Qolaatii
Somalinya	Anjel
Tigrinya	Cumel and Kumel

(Source: Demel and Abeje , 2002)

Figure 2.1 Fruits of *M. kummel* brought to the market in Bahr Dar, northern Ethiopia.
(Source: Teketay *et al*., in preparation)

2.7 Medical use mimusops kummel

The Ethiopian people have been using medicinal plants to treat different diseases over many centuries, though the religious and secular pharmacopoeia had been compiled since 15th century. The traditional medicinal plants are the integral part of the variety of cultures in Ethiopia; resulted in the traditional medical system pluralism (Pankhurst, 1965, 1990; Abebe and Ayehu, 1993).*Mimusops kummel* A. DC. *Eshe, Shiye* is one of the medicinal plants traditionally used for the treatment of diarrhea in Ethiopian folklore medicine. Mimusops kummel fruits are principally used in Ethiopia for the treatment of diarrhea and amebiasis (Teklehaymanot and Giday, 2007). Similarly, the seeds are used to treat ascariasis (Lemmens, 2008).

2.8 Process technology of fruit drying process

1. Fruit Harvest as carefully as possible to reduce bruising and other damage
2. **Inspect and wash:-** Remove moldy, rotten, and badly damaged fruit. Also remove all visible foreign material (physical contaminants): leaves, stems, stalks, sticks and stones. Poor quality raw materials produce poor quality, and perhaps unsafe, finished products. Use wash tanks or special washers with clean, potable water to remove surface contaminants, e.g., pesticide residues, insects, soil or dirt, etc.

3. **Sort or grade: -** By hand select fruits with the same color, size or maturity (fully mature but not over-ripe). Uniform size and maturity are important to get uniform drying times for all pieces. Over-ripe fruits are easily damaged and difficult to dry. Under-ripe fruits have poorer flavor, color and appearance.
4. **Peeling:-**Peel prevents moisture leaving the food and allows faster blanching, sulphur dioxide treatment and drying. Peel by hand using knives or peelers, or using small peeling machines. Check that all traces of peel are removed
5. **Drying:-**The time needed for drying depends on the temperature, humidity and speed of the air, the type of dryer and the size of the food pieces. Check for mould growth, insect contamination and the temperature and time of drying.
6. **Packaging:** - Using an electric heat sealer to produce moisture-proof, airtight plastic bags. Check fill-weight and seal (UNIDO .2004).

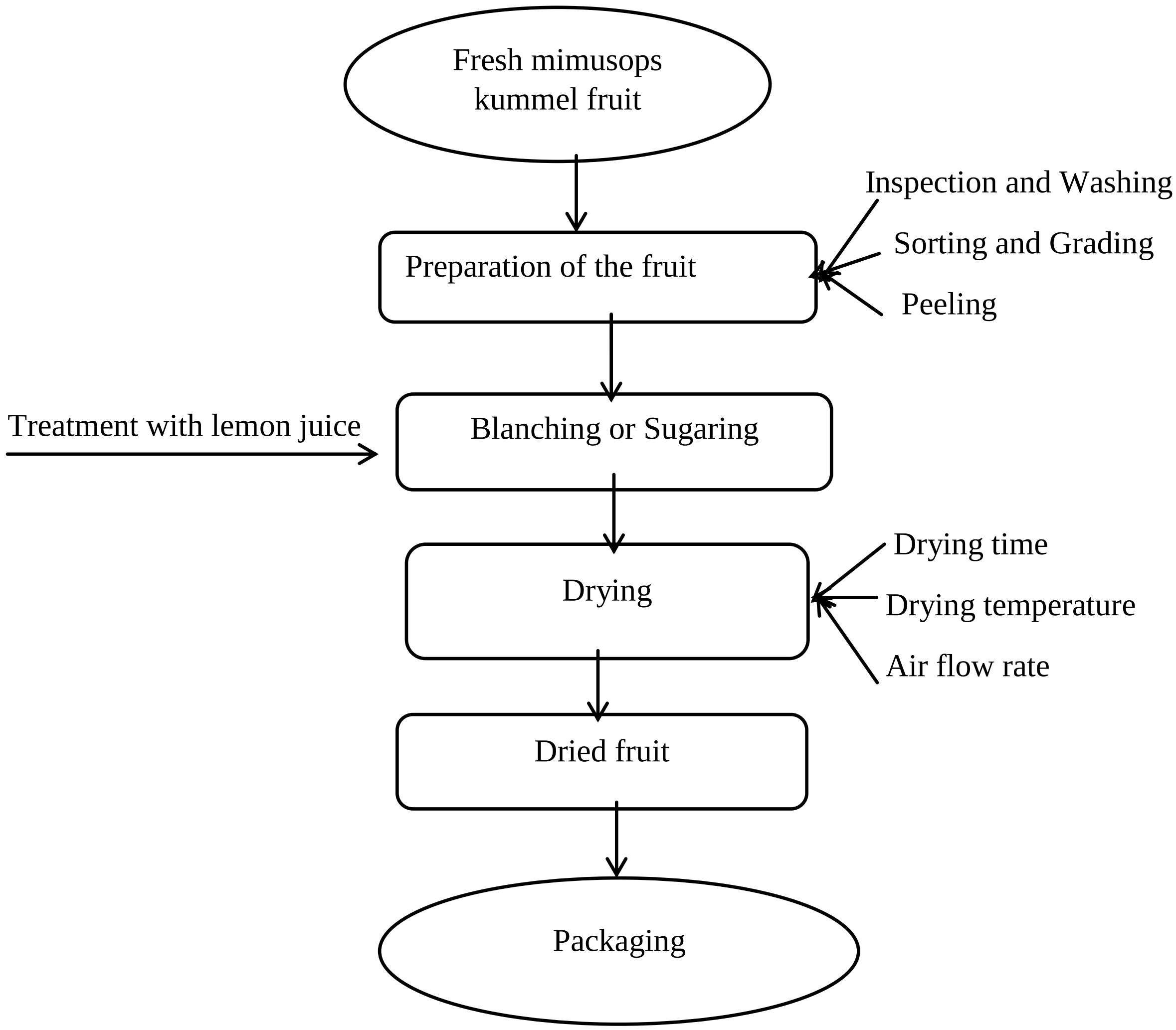

Figure 2.2 *Process flow diagram of dried Mimusops kummel*

2.9 Dried fruit production and Marketing worldwide

Dried fruit is used in consumption or food service packing, mainly consumed as a snack and as an ingredient for breakfast cereals, healthy ready-to-eat snacks and desserts. Bakeries and breakfast cereal mixes are one of the largest end users of dried fruit. Small and medium enterprise competitiveness facility. Organic dried fruits are used primarily as snack, while the portion that is used by the food industry as an ingredient. One factor explaining this is the relatively high price of these natural dried fruits. But limitations in diversity, quality and reliability of supply will also play a role. Organic deep fried banana chips do find a market in the food-industry, for one reason since these are more competitively priced (MMA, 2008).

Dried fruits are a very rich source of minerals and nuts are also rich in proteins. They have numerous healing properties because of the sufficient amount of nutrient components. Each dietologist recommends “a handful” of dried fruits in the diet with a view to healthy nutrition. Among the ten top health benefits in fact, dried fruits consumption supplies an immediate energy surge and causes improvement of the memory (Gyurova, et al., 2014).

2.10 Hot thin layer dryer

Drying is one of the oldest and a very important unit operation; it involves the application of heat to a material which results in the transfer of moisture within the material to its surface and then water removal from the material to the atmosphere (Ekechukwu, 1999, Akpinar and Bicer, 2005). The internal conditions such as moisture content, the temperature and the structure of the product play an important role in the falling rate periods (Panchariya, et al., 2001). Thin layer drying can be described as a drying of one layer sample particles or slices. Due to its thin layer characteristics, we assume that the temperature distribution is uniform, thus making thin layer drying suitable for lumped parameter models. The main mechanisms of drying are surface diffusion on the pore surfaces, liquid or vapor diffusion due to moisture concentration differences and capillary action in granular and porous foods due to surface forces (Erbay et al., 2010).

Drying removes most of the water from fruits to extend their shelf life and to increase their convenience and value. The reduction in weight and bulk also makes transport cheaper and easier although many dried foods are fragile and require packing in boxes to prevent them from being crushed. Different categories of dried foods can be described as high-volume, lower-value crops such as staple cereals and low-volume, higher-value foods such as dried fruits, vegetables herbs and spices (FAO, 1998).

In this method, heated air is brought into contact with the wet material to be dried to facilitate heat and mass transfer; convection is mainly involved. Two important aspects of mass transfer are the transfer of water to the surface of the material that is dried and the removal of water vapor from the surface. The hot air dryers generally used for the drying of piece-form fruits and vegetables are cabinet, kiln, tunnel, belt-trough, bin, pneumatic and conveyor dryers. Energy source to heat the air would be electricity or a renewable energy resource such as solar and geothermal energy. At solar dryers, solar radiation is consumed by air and heated air is ducted to the drying chamber (Tarık, 2007).

2.10.1 Influence of drying process

Drying of agricultural products is the oldest and widely used preservation method. It involves reduction as much water as possible from foods to arrest enzyme and microbial activities hence stopping deterioration. Moisture left in the dried foods varies between 2-30% depending on the type of food. In tropical countries, solar dryers can be used to dry fresh produce when average relative humidity is below 50% during drying period. Drying lowers weights and volume of the product hence lowers costs in transportation and storage. However, drying allows some lowering in nutritional value of the product e.g. loss of vitamin C, and changes of color and appearance that might not be desirable. To avoid discoloration and excessive vitamin losses, treatment with anti-oxidants like citrus (lemon) juice is done. This is however dependent on the fruit or vegetable. After the correct stage of dryness is achieved the product should be removed from the dryer parked, and stored in a dry area (GTZ, 2009).

2.11 Food quality assurance

One of the most important reasons for analyzing foods from both the consumers and the manufacturer’s standpoint is to ensure that they are safe. It would be economically disastrous, as well as being rather unpleasant to consumers, if a food manufacturer sold a product that was harmful or toxic. A food may be considered to be unsafe because it contains harmful microorganisms (e.g., Listeria, Salmonella), toxic chemicals (e.g., pesticides, herbicides) or extraneous matter (e.g., glass, wood, metal, insect matter). It is therefore important that food manufacturers do everything they can to ensure that these harmful substances are not present, or that they are effectively eliminated before the food is consumed. This can be achieved by following “good manufacturing practice” regulations specified by the government for specific food products and by having analytical techniques that are capable of detecting harmful substances. In many situations it is important to use analytical techniques that have a high sensitivity, i.e., that can reliably detect low levels of harmful material. Food manufacturers and government laboratories routinely analyze food products to ensure that they do not contain harmful substances and that the food production facility is operating correctly (McClements, 1999).

CHAPTER THREE

Materials and Methods

3.1 Source of Materials and Sample Preparation

3.1.1 Raw material collection and transportation

A fresh ripe fruit of Mimusops kummel was collected from Amhara region, Ethiopia, located about 595 km north of the capital city Addis Ababa, Ethiopia, in November 2017. The fruit was selected to remove spoiled and damaged fruits during transportation and the fruits have to be carefully cleaned to remove any dirt or insecticide residues.

3.1.2 Location of study

The experiment was conducted in kolfe industrial college. The experiment (drying process) on hot thin layer dryer was conducted in kolfe industrial college and proximate test was analyzed in Ethiopian Public Health Institute (EPHI) and phytochemical analysis was conduct in Addis Ababa University in department food science and nutrition, microbiological and sensory analysis was analyzed in Addis Ababa Institute of Technology (AAIT) in food engineering laboratory. The product was produced by drying of fruit by using hot thin-layer dryer.

3.1.3 Raw material preparation

Remove mouldy, rotten, and badly damaged fruit. Also remove all visible foreign material (physical contaminants). Poor quality raw materials (fruit) produce poor quality, and perhaps unsafe, finished products then Use wash tanks or special washers with clean, potable water to remove surface contaminants, like soil or dirt, etc. By hand select fruits with the same color, size or maturity (fully mature but not over-ripe). Uniform size and maturity are important to get uniform drying times for all pieces. Cut fruits by hand using sharp stainless steel slicing machine and dip fruit in lemon or lime juice for 5-10 minutes. Then separate the fruit from lemon juice and weighed the sample and put to the hot thin layer dryer finally, packed the product by using vacuum sillier.

3.2 Experimental frame work of the research

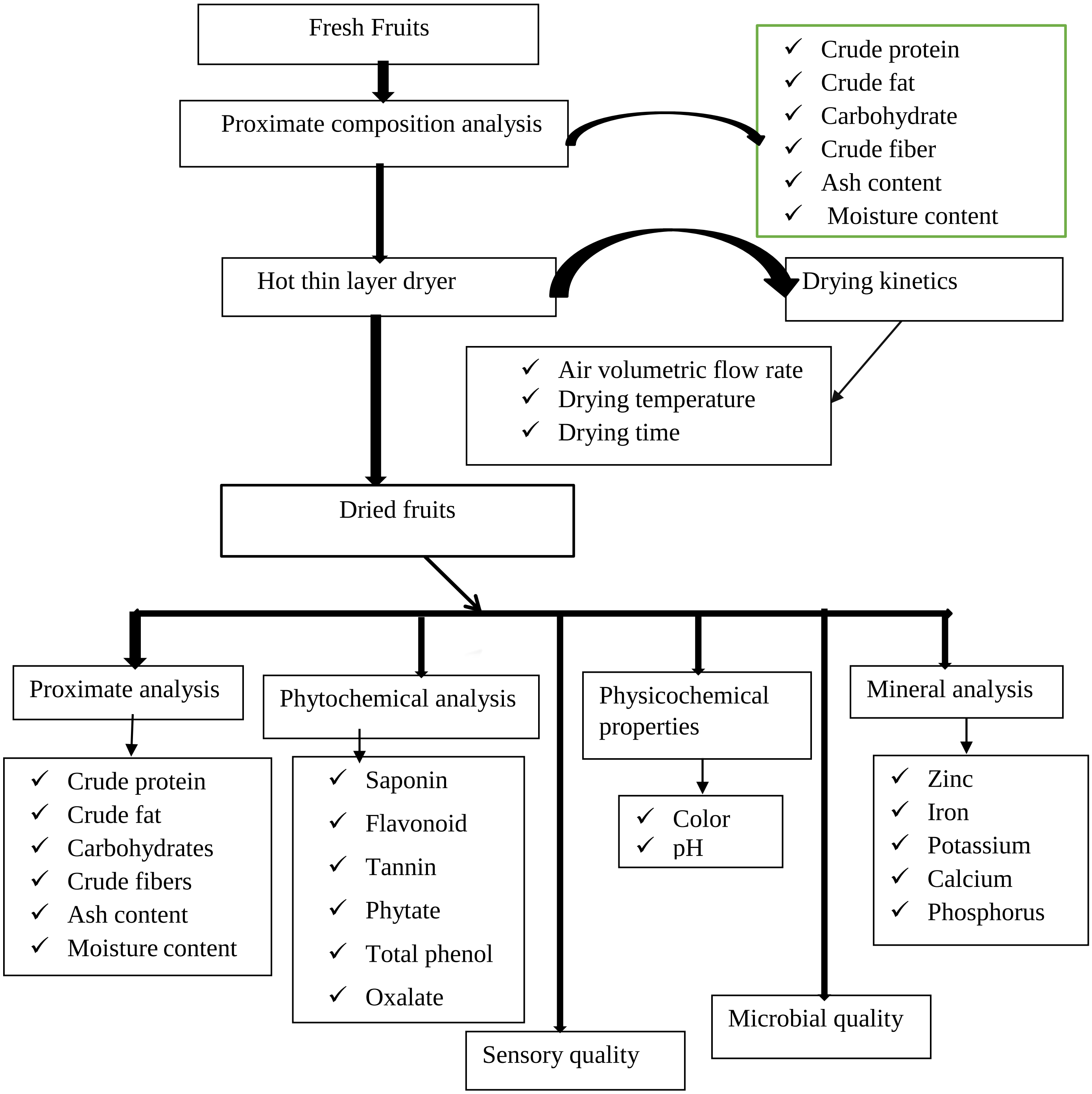

Figure 3.1*Experimental frame work of the research*

3.3 Hot thin layer drying processing

Drying process was performed using laboratory scale hot thin layer dryer (Model GD-100, china). The hot thin layer dryer temperature which varied from 55, 60 and 65 ^{o}c with drying air volumetric flow rate 1 and 2 m^3/s and drying time 4 and 5 hours was selected for the experiment. The temperature, volumetric flow rate and the time of the dryer were controlled by read on control panel board.

Figure 3.2 *Dried mimusops kummel fruit based on experimental design*

3.4 Proximate and mineral Analysis

3.4.1 Moisture content

Moisture content was measured using air oven following official methods of Association of Official Analytical Chemists (AOAC, 2000).Moisture content was the amount of liquid moisture mass found in the total mass of the fresh wet Mimusops kummel. Moisture content of fruit was measured by using weight difference method.

$$\text{Moisture (\%)} = \left(1 - \frac{weight\ of\ dry\ sampe}{weight\ \ of\ wet\ \ sample}\right)*100 \qquad 3.1$$

3.4.2 Crude fat

A sample was extract with petroleum ether for a minimum in a soxlet extractor. The solvent was removed using a steam bath. The flask containing the extracted fat was dried for about 1 h on steam bath.

$$\text{Crude Fat (\%)} = \frac{W2-W1}{W} *100 \qquad 3.2$$

Where: W_1 = Weight of the extraction flask (g)

W_2 = Weight of the extraction flask plus the dried crude fat (g)

W = Weight of sample (g)

3.4.3 Ash content

This test was used to determine the ash content of dried fruit. About 5 -10 gm of dry Mimusops kummel fruit was taken and dry crucibles will be weighed. Then the sample with the crucible was transferred into the muffle furnace and was burnt for 3 to 5 hr at a temperature of 550 ^{o}C and and by allowing to cool in a desiccator and weighing it, the ash content was determined by (AOAC, 2000) using the official method 923.03 and applying a simple formula

$$\text{Ash (\%)} = \left(\frac{\text{weight of } \textit{sample remaining}}{\text{wight of original sample}}\right) * 100 \qquad 3.3$$

Where:

W = Weight in grams of empty dish

W_1 = Weight in grams of the dish plus the dried test material

W_2 = Weight in grams of the dish plus ash

3.4.4 Crude Protein

The crude protein content of the sample was analyzed according to Method AOAC (1984). All nitrogen is converted to ammonia by digestion with a mixture of concentrated sulfuric acid and concentrated orthophosphoric acid containing potassium sulfate as a boiling point raising agent and selenium as a catalyst. The ammonia released after alkalinization with sodium hydroxide is steam distilled into boric acid and titrated with sulfuric acid.

$$mg\ nitrogen = (T - B) * N * 14$$

$$Nitrogen\ /100\ g\ sample = \frac{mg\ of\ nitrogen * 100}{mg\ of\ sample} \qquad 3.4$$

$$Total\ nitrogen\ \% = \frac{(T - B) * N * 14}{\mathrm{w}} * 100$$

Crude Protein = total nitrogen (%) * 5.78

Where: T = volume of sulfuric acid solution used in the titration of test materials.

B=Volume of sulfuric acid solution used in the titration for the blank.

N = normality of the acid

14 = Eq. wt of nitrogen

W = wt. of the sample

3.4.5 Carbohydrates

Carbohydrate content was calculated by difference AOAC, (2012). The difference in value was taken as the percentage total carbohydrate content of the sample.

3.4.6 Crude fibers

A clean and dried thimble containing about 5 g of dried sample and covered with fat free cotton at the bottom and top was placed in the extraction chamber. Then, extraction took place for at least 4hrs according to AOAC (2000) official method 4.5.01. The crude fat content was determined by the formula

$$\textit{Weight of fat } (W_f) = W_a - W_b$$

Where, W_a = weight of extraction flask after extraction

W_b = weight of extraction flask before extraction

$$\textbf{Crude fiber content (g/100)} = \frac{(\mathbf{Wf})(\mathbf{100} - \boldsymbol{moidture}, \%)}{\mathbf{Wd}} \qquad 3.5$$

Where, W_d = dried sample obtained after determination of moisture.

m= % moisture content of the sample

3.4.7 Determination of minerals

An atomic absorption spectrometer with an air/acetylene flame and respective hollow-cathode lamps is used for absorbance measurement. Zinc, potassium Sodium, Calcium and Iron were determined by using atomic absorption method of (Osborne & Voogt, 1978). The metal contents were calculated by using the formula.

$$\text{Metal content in (mg/100g)} = \frac{(A-B)*V}{10*W} \qquad 3.6$$

Where: A=Concentration of sample solution in (mg/ml)

B= Concentration of blank solution (mg/ml)

V= Volume of extract (ml)

W= weight of sample in (g)

3.5 Physicochemical properties

3.5.1 Color

Color measure was made of mimusops kummel stimulus cololimeter which set to L*, a* and b*modes.

- L* value indicate the lightness of fruit (L*= 0 for black) and (L*= 100 for white)

- a* value indicate redness – greenness (a*=100 red and a* = -100 for greenness)

- b* value indicate blueness and yellowish (b* = 100for yellow and b* = -100 for blue)

$$\text{Chroma (c)} = (2a^* + 2b^*)/2 \qquad 3.7$$

Color saturation or intensity

(Huge angle) h = arc tan b*/a* used to determine red, yellow, green, blue, purple or intermediate color between adjacent pairs of these basic color(Dibya et al., 2015).

3.5.2 pH

The pH of samples was measured using omega pH digital pH meter (HANNA, Romania). Standardization of the meter was done using buffer solution of pH 4 and 9.

3.6 Determination of phytochemical in the fruit

3.6.1 Determination of flavonoid

About 50 mg of the sample was extracted repeatedly with 100 ml of 80% aqueous methanol at room temperature. The solution was filtered through Whatmann filter paper No 42 (125 mm). The filtrate was later transferred into a crucible and evaporated into dryness over a water bath and weighed to a constant (Boham and Kocipai-Abyazan, 1974).

3.6.2 Determination of saponin

About 50 mg of the sample was weighed into a conical flask and 100 cm3 of 20% aqueous ethanol was added to the sample. The sample was heated over a hot water bath for 4 h with continuous stirring at about 55^0C. The mixture was filtered and the residue reextracted with another 200 ml 20% ethanol. The combined extracts are reduced to 40 ml over water bath at about 90^0C. The concentrated filtrate was transferred into a 250 ml separating funnel and 20 ml of diethyl ether was added and shaken vigorously. The aqueous layer was recovered while the ether layer was discarded. The purification process is repeated. 60 ml of n-butanol is added. The combined n-butanol extracts were washed twice with 10 ml of 5% aqueous sodium chloride. The resultant solution was heated in a water bath. After evaporation the samples were dried in the oven to a constant weight the weight of saponin were determined in the samples (Obadoni and Ochuko, 2001).

3.6.3 Analysis of phytic acid

Phytic acid was determined spectrophotometrically (Hassan *et al.*,2011; Wheeler and Ferrel1971). Accordingly, 0.2 gram of each sample was extracted with 10ml of 0.2 N HCL for one hour at room temperature and centrifuged at 3000 rpm for 30 minutes. The clear supernatant was then used for phytic acid determination. Two ml of wade reagent (0.03% solution of $Fecl_3.6H_2O$ containing 0.3% sulfosalicylic in water) was added to three ml of the supernatant sample solution, homogenized and centrifuged at 3000 rpm for 10 seconds. Absorbance reading was taken at 500nm using UV-Vis spectrophotometer. Absorbance reading of phytic acidwas calculated from the difference between the absorbance of the blank (3ml of 0.2 N Hcl + 2ml of wade reagent) and that of assayed sample. The amount of phytic acid was calculated using phytic acid standard curve and the result was expressed as phytate in µg/g.

$$\text{Phytic acid in } \mu g/g = \frac{[(A_s - A_b) - \text{Intercept})]*10}{\text{Slope} \times W \times 3} \quad 3.8$$

Where A_s = sample absorbance

A_b = blank absorbance

W = weight of sample

The standard curve was developed using serial dilution of phytic acid standard curve (Y= -0.01x + 0.4558, R^2= 0.9989). Accordingly, phytic acid solution was contain 40 µg/g phytic acid and 0.2N HCL. Three ml of the solution was pipetted in to 15 ml centrifuge tubes and 3ml of 0.2 N HCL to the blank. Two ml of wade reagent was added to each tube and the solution was mixed using vortex mixer. The supernatant was taken and it absorbance were read at 500 nm by using the spectrophotometer.

3.6.4Analysis of tannin

One ml of concentrated HCl was added into 100 ml volumetric flask, which was partially filled with methanol and make up the volume with methanol for preparing of 1% HCl. Vanillin-HCl reagent was prepared separately by dissolving four gram of vanillin in 100 ml of volumetric flask with methanol (solution A) and eight ml of concentrated HCl in 100 ml of volumetric flask and make up the volume with methanol (solution B). Equal volumes of solution A and B were mixed to prepare the reagent (Martin 1982).

One gram of samples was measured in a screw cap test tube.Ten ml of 1% HCl in methanol was added into each test tube containing the sample. The test tube containing the mixture was placed on mechanical shaker for 24 hours at room temperature.The mixture was later centrifuged for five minutes. One ml of the supernatant was then transferred to another test tube and mixed with five ml of Vanillin-HCl reagent and allowed to stand for 20 minutes to complete the reaction. The absorbance was read at 500nm using spectrophotometer.

$$\text{Tannin in mg/g} = \frac{((As-Ab)-Intercept)*10}{Slope \times d \times w} \qquad 3.9$$

3.6.5 Analysis of total phenolic content

Total phenolic content was determined according to (Bhoyar *et al.*, 2011). The sample extraction method for total phenolics is similar to the extraction used to determine antioxidant activity. One ml of each sample extract, which is prepared within the concentrations ranges of 20-160 µl/ml, was adjusted with methanol. One ml of Folin-Ciocalteu reagent (FCR) was pipetted to each test tube containing the sample solution and mixed and incubated for three min at room temperature. After 3 minutes, one ml of saturated Na_2CO_3 solution was transferred to the solution and adjusted to 10 ml with distilled water, mixed and incubated at room temperature. The solution was kept in dark condition for 90 minutes. Finally, absorbance was read at 725nm using UV-VIS spectrophotometer.

3.6.6 Determination of oxalate

Oxalate quantitative determination was carried out using the method reported by **(**Ejikeme et al., 2014 and Munro and Bassir, 1969). Exactly 20cm3 of 0.3M HCl in each wood powder sample (2.50 g) was extracted three (3) times by warming at a temperature of 50∘C for 1 hour with constant stirring using a magnetic stirrer. For oxalate estimation, 1.0 cm3 of 5M ammonium hydroxide was added to 5.0 cm3 of extract to ensure alkalinity. Addition of 2 drops of phenolphthalein indicator, 3 drops of glacial acetic acid, and 1.0 cm3 of 5% calcium chloride to make the mixture acidic before standing for 3 hours was followed by centrifugation at 3000 rpm for 15 minutes. After discarding the supernatant, the precipitate was washed three times using hot water by mixing thoroughly each time centrifugation. Then, to each tube, 2.0 cm3 of 3M tetraoxosulphate (VI) acid was added and the precipitate dissolved by warming in a water bath at $70^{o}C$. Freshly prepared 0.01M potassium permanganate (KMnO4) was titrated against the content of each tube at room temperature until the first pink color appears throughout the solution. The solution was allowed to stand until it returned colorless, after which it was warmed on an electric hot plate at 70∘C for 3 minutes, and retitrated again until a pink color appears and persists for at least 30 seconds.

Titration reaction of oxalate in sample was calculated as

Ratio of reacting ions = one to one ration

From $M_1V_1=M_2V_2$ 3.10

Where M_1 is molarity of KMnO4

M_2 is molarity of extract (oxalate)

V_1 is volume of extract (oxalate)

And V_2 is volume of KMnO4 (Titre Value)

Molecular Weight of $CaCO_3$= 100

Weight of oxalate in titre = $M_2\times$ molecular weight= Xg

100 cm^3 of oxalate extract will contain = $\frac{Y}{2.5}\times$ 100 g = W

Oxalate composition g/100 g = $\frac{W}{2.5}$*100

3.7 Determination of vitamin C (Total ascorbic acid content of fruit)

To the filtered sample solution few drops of bromine water were added until the solution became colored (to confirm the completion of the oxidation of ascorbic acid to dehydro ascorbic acid**)**. Then few drops of thiourea were added to it to remove the excess bromine and thus the clear solution was obtained. Then 2,4- dinitrophenyl hydrazine solution was added thoroughly with all standards and also with the oxidized ascorbic acid. Total vitamin C employing coupling reaction of 2,4-dinitrophenyl hydrazine dye with vitamin C and followed by spectrophotometric determination.

Concentration of Ascorbic Acid

$$\mathbf{mg}_{\text{ascorbic acid}} = \mathbf{M}_{\text{iodine solution}} \times mL_{iodine\ solution} \times 176.12\ \text{g/mole} \qquad 3.11$$

3.8 Energy value calculation (Calorific value)

Energy value (calorific value) is quantified using an indirect calculation method. The three groups of nutrients, which provide the body with energy, are carbohydrates, fats and proteins (Gaman and Sherrington, 1986). One gram of carbohydrate © was assumed to give 15.71kJ energy; one gram of fat (F) 37.71kJ energy and one gram of protein (P) 16.76kJ. Therefore, determination of calorific value (kJ/100g) of dry fruit was determined according to (Osborne and Voogt, 1978). The energy values for one gram of the three groups of nutrients which provides the body with energy were calculated by using specific values of Atwater factors for protein, fat, and total carbohydrate as recommended by (Birch et al.,1980).

3.9 Microbial quality

Prepare the sample then dilute the sample by dilution method using Pour Plate Method, a 25g of sample was taken and serially diluted to 1:10, 1:100 and1:1000. For yeast and mold and total plate count, one ml diluents taken from each and put on sterile Petridis, pour potato dextrea agar and mix with the sample, then incubated at 35 ^{o} C for 48hr finally count the colony (APHA, 1976).

Media preparation for this purpose, potato agar (yeast and mould), XLD (for salmonella and shegella and maccony agar (for total coli form) has been prepared. In the hood the prepared media and the dilute sample was placed and for each dilution the sample inoculated to the media and placed in the incubator in 25 ^{o}C for yeast and mould ,35^{o}C for total coli form and 37^{o}C for shegella.

3.10 Sensory quality analysis

The most important quality attributes of a food to the consumer, are its sensory characteristics (taste, color, texture, appearance and over all Acceptability). These determine an individual's preference for specific products, and small differences between brands of similar products can have a substantial influence on acceptability. So during processing great care must be taken to retain or enhance these properties (Fellows, 2000).

The sensory tests were conducted with twelve panelists. The panelists were asked to give their individual ratings on all the characteristics of dried mimuspos kummel fruit with bread made by addition mimusops kummel fruit as ingredient of including color, taste texture, appearance and overall acceptability using a nine point hedonic scale with 1=Dislike extremely, 5=Neither like nor dislike, 9=Like extremely was used for all attributes measured. Water was provided to rinse the mouth between evaluations.

3.11 Experimental Design and Statistics Data Analysis

The experiment was done with three variables by using general factorial with different level was used to study parameters during drying. The factors that affect hot tin layer dryer with levels are drying temperature with three levels (55,60 & 65 ^{o}C), with two level drying air flow rate (1 and 2 m/s^{3})e and two levels drying time (4 and 5 hr) by using one way ANOVA (Analysis Variance) is used to determine the significance of three factors in two replication.

CHAPTER FOUR

Results and Discussion

4.1 Proximate composition of fresh and dried fruits

4.1.1 Crude protein content

As it is shown in the table 4.1 the protein content of fresh fruit was 2.5±0.05, the analysis is significant difference ($P < 0.05$) was observed on the crude protein content with all drying temperature, air flow rate and drying time. The crude protein content of dried fruit 2.49% was relatively higher at 55^0C drying temperature than that of at 60^0C and 65^0C which are 2.36% and 2.27% respectively.

4.1.2 Fat content

According to AOAC (2000) official method the mean fat contents of the dried mimusops kummel were significantly different ($P < 0.05$) as they were affected by drying temperature the fat content of the fresh mimuspos kummel and dried mimuspos kummel decreases from 1.40% to 1.20% respectively indicated on Table 4.1.

4.1.3 Total carbohydrates

Total carbohydrate of fresh and dried mimusops kummel were determined according to the AOAC method (AOAC, 2012).Dried mimusopps kummel had the highest total carbohydrate content than the fresh mimusops kummel fruit. The analysis results showed that drying temperature had a significant effect on the total carbohydrate content of the dried fruit ($P < 0.001$). From Table 4.1 higher total carbohydrate content 73.96±3.44% was observed at 55 ^{0}C drying temperature,4 hr drying time and 1m3/sec air volumetric flow rate respectively relative to 60,65^oC drying temperature.

4.2 Effect of drying in proximate composition

4.2.1 Effect of drying on Vitamin C content of dried Mimusops kummel

Vitamin C (L-ascorbic acid) is the least stable of all vitamins and will easily be destroyed during processing and storage. Exposure to oxygen, light and prolonged heating in the presence of oxygen during processing will decrease the vitamin C content of foods (Fennema, 1996). The total vitamin C content of the dried mimusops kummel was affected by drying temperature, air flow rate and drying time. The total vitamin C content of the dried mimusops kummel was preserved by dipping of fresh fruit in lemon juice for five minutes before drying due to that the vitamin c content of dried fruit was decreased from 14.48 to12.45 mg/100g (Table 4.1).

4.2.2 Effect of crude protein content

As the result shown on Table 4.1, the analysis is a significant difference ($P < 0.05$) had been observed on the crude protein content with all drying temperature, air flow rate and drying time. The crude protein content of dried fruit 2.49% was relatively higher at 55^0C drying temperature than that of at 60^0C and 65^0C which are 2.36% and 2.27% respectively.

4.2.2 Effect of processing on moisture removal

Moisture content of mimusops kummel was determined according to the AOAC method (AOAC, 2000). The moisture loss of dried mimusops kummel was measured by using an oven dried for three hour at temperature of 105 ^{O}C the drying process was continued until the readings were constant. According (Rob Hesbst and sharontyle , 2015) the final moisture content of dried fruit usually range from 15 to 25%.The moisture contents products obtained in this study were in range and low moisture content of fruit prevents microbial activity and extends the shelf life of the fruit. The analysis shows that there is a significant difference ($P < 0.05$) between the means of moisture content of the dried fruit due to temperature, air flow rate and drying time.

The result in the table 4.1 also indicated that the moisture content is dependent on temperature, air flow rate and drying time, it also affect the final moisture content of product significantly and the affect the quality of dried fruit so that the moisture content of dried fruit decreased from (64±%1.7 to 19.36±0.6%) that indicate the product was in range. The drying time was generally shorter at higher temperatures due to quick removal of moisture.

4.2.3 Effect of processing on energy value

Much of the work of the first part of the twentieth century was directed towards understanding the roles of specific nutrients in intermediary metabolism: the goal of an adequate and healthy diet was to prevent energy and nutrient deficiencies. There is no awareness of the key role that diet plays in the induction or prevention of specific diseases, such as heart disease, strokes, cancer and diabetes mellitus (WHO, 2003). Inadequate energy intake still limits the potential of individuals. Therefore the energy value during processing was increased from 553.26 kJ/100g to

1268.70 kJ/100 g in fresh and dried fruit respectively. These indicated the dried fruit has more energy relative to the fresh one as the result shown on table 4.1.

Table 4.*1* Proximate *composition fresh and dried fruit (%)*

Proximate composition	Fresh fruit	Dried fruit (product)%
Protein	2.54±0.05 ^{g}	2.49±0.13^{g}
Moisture content	64.00±1.70^{b}	19.36±0.60^{d}
Crude fat	1.4±0.04 ^{g}	1.26±0.12^{g}
Ash	2.9±0.06^{g}	2.9±0.09^{g}
Crude fiber	9.87±0.31^{f}	9.87±0.31^{f}
Carbohydrate	29.29±0.20^{c}	73.96±3.44^{a}
Vitamin C(mg/100g)	14.48±0.80^{e}	12.45±0.35^{ef}
Energy(kJ/100g)	553.26±0.26	1268.70±0.7

a-g All Values are means ± SD of the triplicate

Means with the same superscript letters within a row are not significantly different (P > 0.05)

As it is shown in the above table the protein content of the fresh fruit was 2.54 ±0.05% and the total carbohydrate content of the fresh fruit was found 29.29±0.20%. The moisture contains fresh fruit was 64±1.7% reduced to 19.36±0.6 %.the total component of amount of carbohydrate was increase from 29.29±0.20% to 73.96±3.44%. Based on the proximate value obtained the total carbohydrate for the dried was developed.

4.3 Drying kinetics optimization on fruit drying process

The effect of drying air temperature and volumetric flowrate on drying time taken to reach the final moisture content (15 to 25%) is presented in Table 4.2. Drying time was conducted at drying time of 4 and 5 hr, air flow rate 1 and 2 m^3/s at all drying air temperatures respectively. The higher air temperature and volumetric flow rate occurred the lower drying time. Drying at lower temperature and air flow rate with short time was selected from all of experiment due to range of moisture content. From the design experiment out put the drying time of 4hr and 1 min, and air volumetric flow rate of 1.2m3/se and response of final moisture 18.73%.

Table 4.2 *Drying parameter of dried fruits*

Operating parameters			
Temperature (^oC)	**Air flow rate (m^3/sec)**	**Time (hr)**	**Moisture content (%)**
55	1	5	16.50 ± 0.50^d
60	1	5	15.26 ± 0.12^d
65	1	5	14.28 ± 0.55^e
55	2	5	10.00 ± 0.15^f
60	2	5	9.45 ± 0.14^{fg}
65	2	5	8.12 ± 0.04^g
55	1	4	19.36 ± 0.14^a
60	1	5	18.90 ± 0.6^a
65	1	4	17.83 ± 0.35^b
55	2	4	18.87 ± 0.09^a
60	2	4	18.47 ± 0.20^b
65	2	4	17.25 ± 0.24^c

a-g All Values are means ± SD of the triplicate

Means with the same superscript letters with in a column are not significantly different ($P > 0.05$)

4.4 Drying parameter selection based on General factorial design

The data acquired from the experiment were analyzed using Design Expert software. There are different methods of analyzing data in the Design Expert software but General factorial design method was used for different level of operations and determining the drying parameters in different drying temperature, air volumetric flow rate and time. The drying parameters in the dried fruit had a statistical significance of the model terms for each moisture contents. The experiments have been at all improved simplex centroid design points design by General factorial Design Expert software.

The results obtained from the experiment were input in to the software (Appendix VI). based on the output obtained from the software the experiments were done (Appendix IV and VII).from the software result it suggested (Appendix II and IV)with p value <0.0001, predicted R suaqre 0.9961 and predicted R suaqre 0.9883,and prress 1.80 2FI model design was signifcant model and selected for the experimment.

Table 4.3 *Significance Model fit Summary Statistics*

Response	Model	DF	$Mean^2$	F-value	P value	Adjusted R^2	Predicted R^2	PRESS
Moisture content	2FI	3	6.19	112.92	0.0001	0.9961	0.9883	1.80

Where: DF degree of freedom, 2FI Two Factorial design and PRESS Predicted error square.

Relative to other model two factorial design had low PRESS value than the linear and Quadratic model with large adjusted R square and predicted R^2 value.

The adjusted R2 is a measure of the amount of variation about the mean explained by the model, adjusted for the number of parameters in the model. The predicted R^2 measures the amount of variation in new data explained by the model. PRESS measures how well the model fits each point in the design. PRESS is the sum of the squared differences between the estimated values and the actual values over all the points. A good model will have a low RMSE, a large predicted R2, and a low PRESS. The R^2 is defined as the ratio of the explained variation to the total variation and is a measure of the degree of fit (Ibrahim, et.al, 2010).

From the output of model (2FI) predicted equation for moisture content

Moisture content = 15.52 -1.07*A- 2.89* B -1.45 C -0.23* A * B - 0.051 * A * C -1.23 * B * C
Where A, B and C represent temperature, drying time and drying volumetric air flow rate respectively. From the above equation in section 4.4 developed dried fruit with higher temperature, lower air flow rate and drying time.

4.4.1 Numerical optimization

The numerical optimization finds a point that maximizes the desirability function. The Factorial Design Expert program randomly picked a set of conditions from which to start the experiment for desirable results and kinds the results. The Factorial Design Expert program selected 10 solutions/formulations which can be the best solution (Appendix V). Appendix V also shows how well the responses satisfied the criteria and the overall drying desirability. Desirability value for the whole solutions is 1. This shows all solution can be considered as a good solution (Ibrahim, et.al, 2010; Cristiane et.al, 2006).

4.4.2 Graphical optimization

Factorial Design Expert Software provides contour plots over the design space and the contours are plotted on the 2-dimentional rectangle and indicated a region that best predicts the predefined responses.

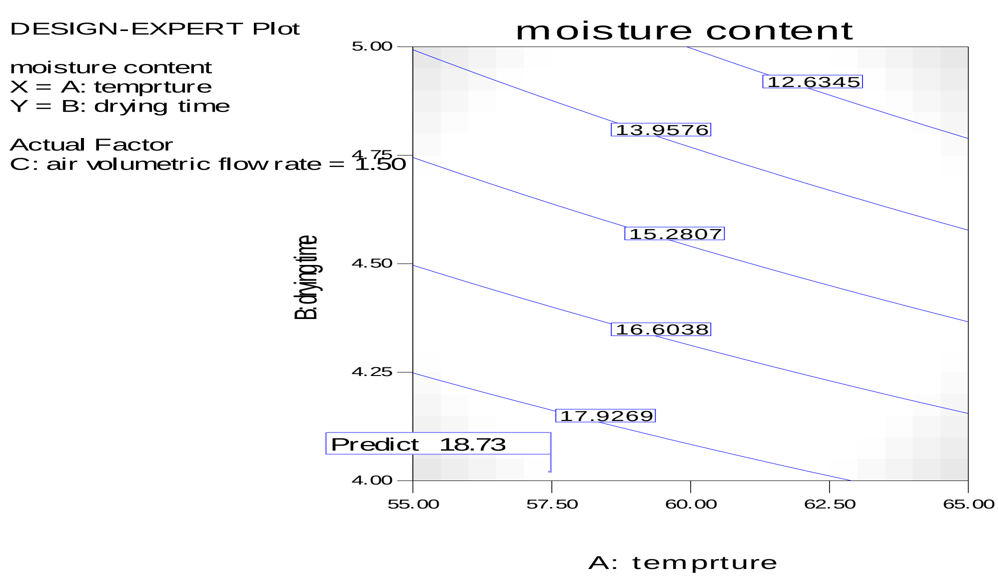

Figure 4.1 *Predicted Contour plots for drying*

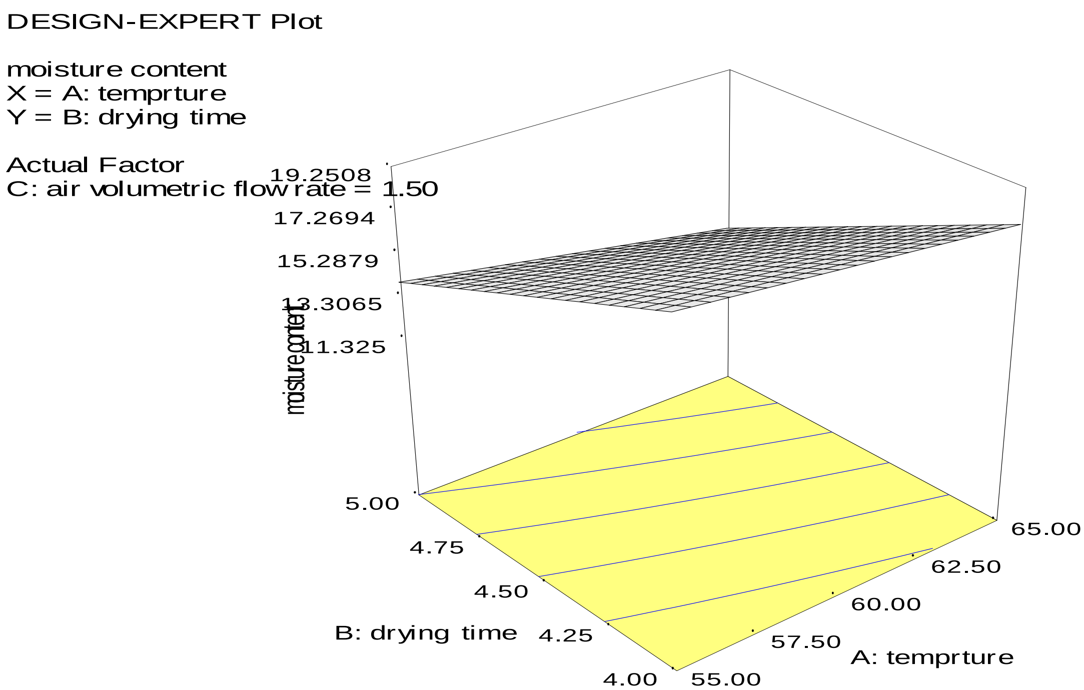

Figure 4.2 *Counter plots for drying*

From the above graphical result shown that the fruit which dried with temperature 57.09 ^{o}C , drying volumetric flow rate 1.15m^3/sec and 4hour and 12 minute drying time with response of moisture content of 18.42% was selected respectively. The selection of drying parameter was based on the final moisture content of final product.

4.5 Micronutrients composition of dried mimusops kummel fruits

Dried fruits are a very rich source of minerals and also rich in proteins. They have numerous healing properties because of the sufficient amount of nutrient components. Each dietologist recommends “a handful” of dried fruits in the diet with a view to healthy nutrition (P. Kavya, 2014). From the analysis shown as the mineral content of dried fruit was significantly affected ($p<0.005$) by drying parameter. The K, Na, Fe, Zn and Ca content of dried fruit was (K 36.6 mg/100g, Na17.2 mg/100g, 150.1 mg/100g, 25.4 mg/100g and Ca 81.4 mg/100g) respectively. As the result shown on (Table 4.4) the fruit is rich source of iron 150.1 mg/100g and it is one of the essential nutrients in all age level especial in children and pregnant women.

According to Mosha *et al*., (2000) Zinc is an important micronutrient for infants and young children since it is used in the synthesis of enzymes, hormones, proteins and other materials that promote optimal physical and mental growth. Zinc also enhances the body’s immune system thus, protecting children from infections. Eating or taking enough potassium every day to feel best and to help prevent certain chronic conditions. From Table 4.4 the fruit had 3.66±014 amount of potassium.

According to John *et al*., (2000), the proportion of calcium which is said functions as a constituent of teeth, bone, muscle regulation, rickets in children and ostemalacia in adults is happened due to deficiency of calcium as the result shown as on Table 4.3Mimusops kummel to had calcium contents of 81.4 ± 0.60 mg/100g that indicated the fruit is rich source of calcium.

Table 4.4 *Micronutrient content of products*

Micronutrients	Metal content (mg/100g)
Iron	150.1 ± 5.90^{a}
Calcium	81.4 ± 0.60^{b}
Potassium	36.6 ± 1.40^{c}
Zinc	25.4 ± 1.60^{d}
Sodium	17.2 ± 0.37^{f}

a-e All Values are means ± SD of the triplicate

Means with the same superscript letters within a column are not significantly different (P>0.05)

4.6 Phytochemical contents for dried Mimusops kummel

Phytochemicals are the chemicals that present naturally in plants. Nowadays these phytochemicals become more popular due to their countless medicinal uses. Phytochemicals play a vital role against number of diseases such as asthma, arthritis, cancer etc. unlike pharmaceutical chemicals these phytochemicals do not have any side effects. Since the phytochemicals cure diseases without causing any harm to human beings these can also be considered as "man- friendly medicines(k.sahira and L.Cartine,2015).As shown on the (Table 4.5) dried mimusops kummel was rich in (Saponnin 6000±2.00) and other phytochemical component that indicated the product had potential to treat disease.

- **Oxalate content**

The amount of oxalate in fruit was 18.9±0.30 mg/100g this indicate lower amount of it safe to consume. The oxalate content in this study was similar to result reported by (Anhwange *et al.*,2015). A diet high in oxalate increases the risk of renal calcium absorption and has been implicated as a source of kidney stones (Erukainure *et al*., 2010). Mimusops kummel fruit has lower amount of oxalate. It is therefore consumption of the fruit will reduce bio accessibility of nutrients or cause any unwanted health problem such as kidney stone.

Table 4.5 *Phytochemical content of dried Mimusops kummel*

Phytochemical components	(mg/100g)
Saponnin	6000±2.00[a]
Tannin	294.20 ±0.55[b]
Phytate	104.74±2.18[c]
Total phenol	57.465±1.02[d]
Flavonoid	46.45±2.04[e]
Oxalate	18.90±0.30[f]

a-f All Values are triplicate means ± SD of the triplicate

Means with the same superscript letters within a column are not significantly different (P > 0.05)

- **Physicochemical properties of fruits**

The physicochemical properties of the fruit were determined (color and pH of fresh fruit). The color of fruits was determined by LAB method (chromameter CR400).

Table 4.6 *Physicochemical properties of fruits*

Physicochemical properties	Fresh fruits
pH	5.14±0.252
Color	L* =46.39±2.88
	a* =29.28±4.50
	b* =44.08±4.08

Color measurement of Mimusops kummel were made using portable CR-400 this stimulus colorimeter which set to L*, a*, and b *models. According to (Thomas, 2005) L* value in the table 4.6 was positive the color of fruit is bright. Positive value of a* also indicted the fruit was reddish and the b* value also indicated that color of fruit was yellowish.

4.6 Microbial quality of dried mimusops kummel

The microbiological test as the results shown in the table 4.7 for yeast and mold, Total coliform and Salmonella and shegella species for all dried mimusops kummel was found to be safe < 1 x 10^4 respectively. Salmonella and shigella species were not isolated for all products. The result shown in the Table 4.7 drying is the best way to preserve fruit for several months.

Table 4.7 *Total yeast and Mold, Total coliforms & Salmonella and shegella content of dried fruits*

Sample	Total coliforms(cfu/g)	Yeast and mold (cfu/g)
S_1	TFTC	TFTC
S_2	TFTC	TFTC
S_8	$3x10^3$	$5.4x10^3$
	$3.82x10^3$	$6.2\ x10^3$
	$4.3x10^3$	$9.2x10^3$
S_3	TFTC	TFTC
S_{11}	$6.2\ x10^2$	$4.1x10^2$
	$4.2\ x10^2$	$3.13\ x10^2$
	$8.4\ x10^2$	$3.2x10^2$
S_{10}	$2.5x10^3$	TFTC
	$3.1\ x10^3$	TFTC
	$2.7x10^{-3}$	TFTC
S4	TFTC	TFTC
S5	TFTC	TFTC
S_6	TFTC	TFTC
S7	TFTC	TFTC
S9	TFTC	TFTC
S12	TFTC	TFTC

TFTC (Too Few To Count)

4.7 Sensory quality

The six dried mimusops kummel fruit were (S1-S6), which selected for sensory evaluation.it includes evaluation of taste, color, texture, appearance and overall acceptance. In order to reduce the number of samples to be provided to the panel, preliminary product selection was performed based on final moisture content of the products and six products were selected for the sensory evaluation.

Table 4.8 *Sensory evaluation of dried mimusops kummel*

Operating parameter	Code	Taste	Color	Texture	Appearance	Over all Acceptability
55,1,4	D1	7.00 ± 1.00^{a}	7.67 ± 1.53^{a}	6.33 ± 1.08^{a}	5.67 ± 1.53^{b}	7.67 ± 1.15^{a}
60,1,4	D2	6.67 ± 0.52^{a}	7.00 ± 1.65^{a}	5.33 ± 1.53^{b}	6.67 ± 1.08^{a}	6.67 ± 1.53^{a}
65,1,4	D3	6.67±0.52a	7.33 ± 1.53^{a}	6.67 ± 1.21^{a}	6.00 ± 1.53^{b}	6.67 ± 1.15^{a}
55,2,4	D4	7.33 ± 0.52^{a}	6.33 ± 1.53^{b}	6.67 ± 1.31^{a}	7.00 ± 1.65^{a}	6.33 ± 1.53^{b}
60,2,4	D5	5.00 ± 1.00^{b}	6.00 ± 1.00^{b}	5.67 ± 1.52^{b}	5.67 ± 1.53^{b}	5.67 ± 0.58^{b}
65,2,4	D6	5.33 ± 0.52^{b}	6.33 ± 1.15^{b}	5.33 ± 1.56^{b}	6.00 ± 0.73^{b}	6.67 ± 1.15^{a}

a-b All Values are mean ± SD

Means with the same superscript letters within a column are not significantly different (P>0.05)

Where, Operating parameter are 55,60 and 65 are drying temperature in(^{0}C)

1 and 2 are air flow rate in (m^3/s) and 4 is drying time in (hr).

D, Dried mimusops kummel fruit

Texture of dried mimusops kummel fruit was tested in terms of their ability to be easily crushed in mouth in addition all products the result of the ranged 5.33 to 7.00 like slightly. The color of the product was perceived as significantly different by the panelist and color of the six product was in the mean score of D1 (7.67) like moderately as compared to D4, D5, and D6. D4and D2 gave an appearance that was the like slightly respectively.

From table 4-8, the overall acceptability of the products was observed as significantly different by the panelists. The mean score data for the overall acceptability (Table 4-8) shows that, the mean score of D1 (7.67) were significantly liked as compared to the others. D5 was the least rated overall acceptable product with mean scores of 5.67.The sensory results indicated that the fruit dried with a temperature of 55^0C, air volumetric flow rate $1m^3$/sec and drying time 1 hr was perceived as the most accepted product, as compared to the other product dried with different drying parameters.

CHAPTER FIVE

5. Conclusions and Recommendations

5.1 Conclusions

Wild edible fruits are very important for different purposes they are play role in the food and agriculture. Mimusops kummel is one of the underutilized indigenous wild edible fruit in Ethiopia Mimusops kummel is one of indigenous fruit as literature indicates there is no information about the fruit however this study analyzes nutrition value, phytochemicals, minerals and vitamin c in the fruit. The dried fruit are consumed as snack and it also added to different food product as ingredient

Drying behavior of fruit was investigated by using a hot-thin layer dryer with different drying parameter such as, drying air temperatures of 55,60 and 65^{o}C , drying time 4 and 5 hour and air flow rate of 1 and 2 m^3/s. As the experiment indicated the higher air temperature and higher air flow rate occurred the lower drying time. The least degradation of vitamin C occurred at 55^{o}C of air temperature and 1.0 m^3/s air flow rate and 4 hr drying time. Increased temperature and decreased air flow rate and drying time increased degradation of vitamin C in mimusops kummel the amount of vitamin c (ascorbic acid) in fresh and dried fruit was 14.48±0.8 and 12.45mg/100g respectively..

Currently in Ethiopia there is no fruit processing industry involved in dried fruit development process. Most fruit processing industries are interested in production of juices. Finally, this result indicated hot thin layer fruit drying processing method decrease the growth of undesirable microorganism, Yeast and Mold, Total coliform and salmonella and shegella. This shows clearly that the importance of drying in the aspect of fruit preservation.

5.2 Recommendations

The consumption and utilization of some wild fruits have been increasing, and some wild fruits have been developed into processed fruit products like jam and juice. In the future, for full utilization of wild fruit resources, more bioactivities of wild fruits should be evaluated, and bioactive components should be isolated and identified.

- Mimusops kummel is recommended to be used as source of macronutrients, and recommended to be used as an ingredient for making of food product.
- More research has to be taken on the post-harvest handling and preservation.
- Mimusops kummel fruit should also be recommended in iron and zinc deficiency populations since it is reach in iron and Zinc because of this it can also has potential used as an ingredient for production of complementary foods.
- For preventive of cancer and other diseases, regular consumption of *mimuspos kummel* fruit should be encouraged. As the research indicate *mimusops kummel* fruit is contain significant amount of phytochemicals.
- This research can use as reference for small and medium scale for production of dried fruit from different kinds of fruits.
- Further study should be conducted on the product development like jam, juice and other fruit product.

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Appendices

Appendix- I. Summary of Mixture Design Expert for Drying

Component	Name	Unit	Type	Lower actual	Higher actual	Lower code	Higher code
	Drying temprature	^{o}C	Drying	55	65	-1	1
	Air flow rate	$m^{3/}s$	Drying	1	2	-1	1
	Drying time	hr	Drying	4	5	-1	1
Response	Name	Unit		Analysis	Min	Max	Ration
	Moisture content	%	12	2FI	8.52	19.36	2.272

Apendix II Fit Summary table for Moisture content response

Source	Sum of square	Df	Mean Square	F value	P value (Prob > F)	
Mean	2891.07	1	2891.07			
Linear	134.58	3	44.86	19.05	0.0005	
2FI	18.56	3	6.19	112.97	< 0.0001	Suggested
Quadratic	0.095	1	0.095	2.12	0.2187	Aliased
Cubic	0.18	3	0.095	84.33	0.0798	Aliased
Residual	7.042E-004	1	7.042E-004			
Total	3044.48	12	253.71			

Appendix- III. ANOVA for Moisture content

Source	Sum of square	DF	Mean square	F value	P value	
Model	153.14	6	25.52	465.99	< *0.0001*	significant
2FI	*9.18*	1	*9.18*	*167.61*	< *0.0001*	
	100.34	1	*100.34*	*1831.96*	< *0.0001*	
	25.06	1	*25.06*	*457.46*	< *0.0001*	
	0.44	1	*0.44*	*7.98*	*0.0369*	
	0.021	1	*0.021*	*0.38*	*0.5628*	
	18.11	1	*18.11*	*330.56*	< *0.0001*	
Residual	0.27	5	0.055			
Total	153.42	11				

Appendix- IV. Model Summary for Moisture content response

Source	Standard deviation	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	1.53	0.8772	0.8312	0.7167	43.47	
<u>2FI</u>	<u>0.23</u>	<u>0.9982</u>	<u>0.9961</u>	<u>0.9883</u>	<u>1.80</u>	<u>Suggested</u>
Quadratic	0.21	0.9988	0.9968	0.9881	1.83	Aliased
Cubic	0.027	1.0000	0.9999	0.9990	0.15	Aliased

Appendix- V. Executed Numerical Optimization report for drying responses

Number	Temperature	Dying time	Air flow rate	Desirability	Moisture content
1	57.09	4.83	1.15	1	16.21
2	64.45	4.82	1.26	1	15.73
3	63.27	4.75	1.76	1	12.78
4	63.40	4.42	1.32	1	18.42
5	63.65	4.49	1.41	1	17.94
6	55.86	4.76	1.03	1	11.47
7	62.55	4.35	1.54	1	14.47
8	62.09	4.51	1.06	1	16.67
9	59.71	4.84	1.01	1	10.74
10	63.87	4.98	1.35	1	12.80

Appendix- VI : an augmented simplex general factorial design response value

Run	Factor 1 temperature	Factor 2 Volumetric flow rate	Factor 3 Drying time	Response moisture content
1	55	1	4	19.36
2	60	2	4	18.47
3	60	1	5	15.26
4	65	2	4	17.25
5	6	1	5	14.15
6	60	1	4	18.90
7	55	1	5	16.50
8	65	1	5	17.63
9	65	2	4	8.52
10	55	2	4	18.87
11	55	2	5	11.39
12	60	2	5	9.96

Appendix- VII. Ballot for the sensory evaluation

Sensory score card using nine point hedonic scale for dried mimusops kummel sample

Panelistcode/Name__________________Date__________________Age________

Instruction: Kindly TASTE and EVALUATE each sample using the scale provided below and place the corresponding score on the space provided that best reflects your feelings about the sample. Choose the descriptor which, in your option, is the most applicable to the characteristics being evaluated.

You are presented with food sample. Please taste and tick √ that describe how you feel about the sample

Characteristics &desirability	Sample code	S1	S2	S3	S4	S5	S6
Taste							
Color							
Texture							
Appearance							
Overall acceptability							
Comment							

Characteristics

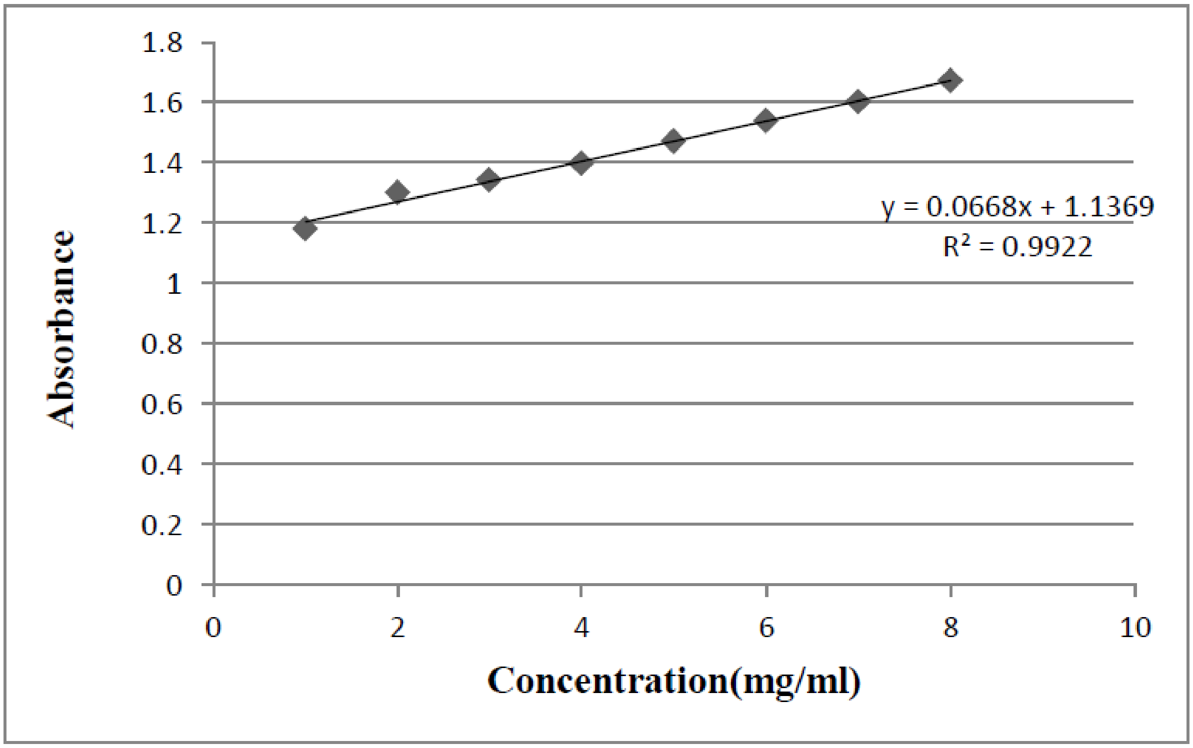
1. Like slightly 2. Like moderately 3. Like very much
4. Like extremely 5. Dislike extremely 6. Dislike very much
7. Is like moderately 8. Dislike slightly 9.Neither like nor dislike

Overall acceptability

1. Acceptable slightly 2.Acceptable moderately
3. Acceptable very much 4.Acceptable extremely
5. Extremely unacceptable 6.Very much unacceptable
7.Moderately unacceptable 8.Slightly unacceptable
9. Neither acceptable nor unacceptable

Please rinse your mouth with water before testing each sample

Appendix VIII Garlic acid standard curve



Gallic acid standard curve

Appendix-IX Experimental picture

Hot thin layer dryer (GD-100, Chaina,2016)

Fresh *mimuops kummel* fruits (ishe)

Drying process

Sample preparation