# ASSESSING THE EFFECT OF PROCESSING TECHNIQUES ON PHYSICAL ATTRIBUTE, STORAGE AND NUTRITIONAL COMPOSITION OF WILD MUSHROOM (*TERMITOMYCES* SPP) AND OYSTER MUSHROOM (*PLEUROTUS OSTREATUS*)

**BY**

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# DECLARATION

I, GAMELI KWABLA KOKOTI, author of this thesis, do hereby declare that except for references to other peoples' work, which have been duly recognized and cited, this is my original scientific research work. It was done in partial fulfillment for Masters in Philosophy Degree, Crop Science (Post harvest science and technology) and was submitted to the Department of Crop Science, College of Agriculture and Consumer Sciences of the University of Ghana.

This work has neither in whole nor in part been submitted for any degree elsewhere.

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# ABSTRACT

The study is aimed at assessing the effect of processing techniques on physical attribute, storage and nutritional composition of wild mushroom (*Termitomyces* spp) and oyster mushroom (*Pleurotus ostreatus*) at the Nutrition Laboratory of Noguchi Memorial Institute, Legon. A structured questionnaire was used to collect information on farmer's methods of harvesting, managing and reducing postharvest losses of wild mushrooms. The questionnaire was pre-tested on 50 participants that were randomly selected from the Kpelezo community. Fresh oyster and wild mushrooms harvested from wheat straw and termite hill respectively were procured for the study. The fresh mushrooms were processed using sun drying, baking with sun drying, blanching with sun drying and mud oven drying. Proximate composition analysis was carried out on the fresh and the processed samples to determine the nutrient composition using Atomic Absorption Spectrophotometer. It was observed that mud oven dried preserved the nutrient composition of the mushroom better than the other methods. Blanched samples had lower nutrient composition due to leaching of the nutrient into the salt solution. Sun dried oyster mushroom maintained its original colour and flavour but had higher moisture content. All the other processed products had a creamy and brown colour. Products stored in the refrigerator had lower moisture content as compared to those stored at room temperature due to moisture ingress from the product to the storage environment. The differences in moisture contents between the two packaging materials were insignificant.

# DEDICATION

This work is dedicated to my lovely parents, Mr. and Mrs. Kokoti and my siblings, Michael, Jack, Isaac, Lizzy, Peace, Akos for their prayers, support and care shown to me throughout my stay on campus. I also dedicate this work to my friends, Yusif, Evans and Samuel.

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# LIST OF ABBREVIATIONS

$^{o}$C – Degree Celsius

g – gram

mg – milligram

ml – millilitre

kg – kilogram

pH – power of hydrogen

*et al*. – and others

% – percent

nm – nanometer

µg – microgram

ppm – part per million

Kcal. – Kilocalorie

AAS – Atomic Absorption Spectrophotometer

# CHAPTER ONE

## 1.0 INTRODUCTION

Mushroom is a macrofungus with a distinctive fruiting body, large enough to be seen with the naked eye and to be picked by hand (Chang and Miles, 1992). All mushrooms belong to the kingdom of Fungi, a group very distinct from plants, animals and bacteria (Oei, 2003). They lack chlorophyll hence depend on other organisms for food (Oei, 2003). Most of the cultivated mushrooms belong to the phylum, Basidiomycetes, which produce their spores on basidia while another important group are Ascomycetes, which produce their spores in asci (Oei, 2003; Arés *et al*., 2007). Mushrooms strive well at relative humidity level of around 70-80% and moisture level of 50-75%. There are about 69,000 known mushroom species of which 2,000 are regarded as edible mushrooms (Chang and Tropics, 1991). Edible mushrooms have been collected and consumed by people for over thousand years ago. Archaeological record reveals edible mushroom species associated with people living 13,000 years ago in Chile, but it was in China where consumption of wild fungus was first reliably noted several hundred years (Boa, 2004). Some wild species harvested in Ghana are *Termitomyces spp*, *Volvariella volvacea*, *Coprinus spp*, *Cantherellus aurantiacus* (Obodai, 2001).

Total commercial mushroom production worldwide has increased more than 21 times in 35 years, from about 350,000 tons in 1965 to about 7.5 million tons in 2000 (Boa, 2004). From 2000 to 2009, global production increased to 67% excluding unofficial production figures emanating from China (Verma, 2013).

Mushrooms are rich in non-starchy carbohydrates, proteins, dietary fibre, minerals, and vitamin-B and are quite low in fat value (Dunkwal *et al*., 2007). The proteins of mushroom are of high quality and rich in various essential amino acids. With regard to their good nutritional and high digestibility values mushrooms are gaining importance in today's healthy diet (Dunkwal *et al*., 2007). However, in the countryside and forest regions, several species of wild mushrooms are collected for consumption. During the onset of the rainy season, when mushrooms are abundant, most people in the rural areas collect them from the forests for home consumption and sell for extra income (Apetorgbor *et al*., 2005).

Despite its importance, the figures for Ghana's mushroom production over the years were not known even after the introduction of the National Mushroom Development Project in 1990 (Sawyerr, 2000) to produce exotic mushrooms such as *Pleurotus* spp. The introduction only brought about small scale mushroom farms mostly for urban unemployed while the technologies developed for the straw mushroom, *Volvariella volvacea*, had not been adequately transferred to the rural communities (Apetorgbor *et al*., 2005).

Due to its perishable nature, mushrooms are susceptible to a wide range of pests and diseases (Cha, 2004). Common pests of mushrooms include mites, midges, millipedes and nematodes. Some of these pests damage the fruiting bodies and attack the mycelium in the soil while others like nematode tunnel through the stalk (Oei, 2003). Other factors such as dehydration and enzymatic browning affect mushroom quality.

## 1.1 Rationale of the Study

A lot of attention has been given to the preservation of mushrooms with little interest in the effect of preservation techniques on nutritional quality. Over the years, several methods have been used to extend the storage life of both fresh and processed mushrooms (Oei, 2003; Rai and Arumuganathan, 2008). In the preservation and use of these methods to extend shelf life, manufacturers and consumers are more concerned with the physical attributes and the organoleptic properties of the final product. This emphasis has led to the neglect by manufacturers and consumers of the need to be concerned with the effect these methods have on the nutritional composition of the final product. The study therefore focused on drying of Wild mushroom (*Termitomyces* spp) and Oyster mushroom (*Pleurotus ostreatus*) and its effect on nutritional composition of the product. The study would probed the effect of drying on storage and physical attributes of the mushrooms and also determined the most effective and efficient method for preserving *Termitomyces* spp and *Pleurotus ostreatus* and furthermore the optimum temperature for preventing nutritional loses while maintaining the quality of the mushroom. Consumer analysis would be carried out to ascertain the organoleptic properties of the dried products by converting some portion into mushroom powder to evaluate farmers' practice of preservation. The study would investigate the type of packaging material ideal for long term preservation. The study would assist the people of Kpelezo and its environs to use the ideal method to preserve the big haul of wild mushrooms they harvested during the peak season for future sales and use.

## 1.2 Objectives

1. To assess the methods used by wild mushrooms farmers to reduce postharvest losses
2. To determine the optimum conditions for drying mushrooms
3. To evaluate sensory properties of the dried mushrooms using mushroom consumers
4. To study the effect of packaging materials on the shelf life of dried mushroom

# CHAPTER TWO

# 2.0 LITERATURE REVIEW

## 2.1 Botany of Mushrooms

A **mushroom** (or **toadstool**) is the fleshy, spore-bearing fruiting body of a fungus, typically produced above ground on soil or on its food source. The standard for the name "mushroom" is the cultivated white button mushroom, *Agaricus bisporus*; hence the word "mushroom" is most often applied to those fungi (Basidiomycota, Agaricomycetes) that have a stem (stipe), a cap (pileus), and gills (lamellae, sing. lamella) or pores on the underside of the cap (Oei, 2003; Wikipedia, 2012).

"Mushroom" describes a variety of gilled fungi, with or without stems, and the term is used even more generally, to describe both the fleshy fruiting bodies of some Ascomycota and the woody or leathery fruiting bodies of some Basidiomycota, depending upon the context of the word (Wikipedia, 2014).

Forms deviating from the standard morphology usually have more specific names, such as "puffball", "stinkhorn", and "morel", and gilled mushrooms themselves are often called "agarics" in reference to their similarity to *Agaricus* or their place Agaricales. By extension, the term "mushroom" can also designate the entire fungus when in culture; the thallus (called a mycelium) of species forming the fruiting bodies called mushrooms; or the species itself (Wikipedia, 2014).

Generally, plants make their food using the sun's energy (photosynthesis), while animals eat, then internally digest, their food. Fungi do neither: their mycelium grows into or around the food source, secretes enzymes that digest the food externally, and the mycelium then absorbs the digested nutrients. There are exceptions to these generalizations; some organisms are placed into their respective kingdoms based on characteristics other than their feeding habits (Ministry of Forest Range, 2014).

Some mushrooms are capable of digesting wood, breaking it down into the primary components of forest soils. They also decay other dead plant and animal matter. A forest in which nothing rotted would soon be choked with accumulating dead leaves and woody material, and starved for essential minerals and other nutrients bound up in the undecomposed debris. (Ministry of Forest Range, 2014)

Many mushrooms form partnerships with roots of living trees, and the resulting fungus-root is called a mycorrhiza. The mushroom's mycelium weaves itself around the root and actually alters the shape of the root. The mushroom absorbs water and minerals for the tree, but in return the tree gives the mushroom nutrients, too. Since both partners benefit from each other, their alliance is considered a symbiotic relationship (Chang and Miles, 1989; Ministry Forest Range, 2014).

Mushrooms are divided into four categories: (1) those that are fleshy and edible fall into the edible categories, e.g. *Agaricus bisporus*; (2) those that are considered to have medicinal applications are referred to as medicinal mushrooms, e.g. *Ganoderma lucidum*; (3) those that are proved to be or suspected of being poisonous are named poisonous mushrooms, e.g. *Amanita phalloides*; (4) those in a miscellaneous category, which includes a large number of mushrooms whose properties remain less well defined. These may tentatively be grouped together as “other mushrooms” (Hawksworth *et al.*, 1997; Chang and Miles, 1989).

**Edible mushrooms** are the fleshy and edible fruit bodies of several species of macrofungi (fungi which bear fruiting structures that are large enough to be seen with the naked eye). They can appear either below ground (hypogeous) or above ground (epigeous) where they may be picked by hand (Chang and Miles, 1989). They have the fruiting bodies which are nutritious and delicious in taste thus are consumed by the human beings (Mahmood *et al*., 2012). Edibility may be defined by criteria that include absence of poisonous effects on humans and desirable taste and aroma (Mattila *et al*., 2000). Edible mushrooms are consumed by humans as comestibles for their nutritional value and they are occasionally consumed for their supposed medicinal value. Mushrooms consumed by those practicing folk medicine are known as medicinal mushrooms (Ejelonu *et al*., 2014). While hallucinogenic mushrooms (e.g. Psilocybin mushrooms) are occasionally consumed for recreational or religious purposes, they can produce severe nausea and disorientation, and are therefore not commonly considered edible mushrooms (Boa, 2004).

Apart from their edibility and nutritional value, mushrooms have potential medicinal benefits (Boa, 2004; Chan, 1981). **Medicinal mushrooms** are mushrooms or extracts from mushrooms that are thought to be treatments for diseases, yet remain unconfirmed in mainstream science and medicine, and so are not approved as drugs or medical treatments (Sullivan *et al*., 2006). Such use of mushrooms therefore falls into the domain of traditional medicine. Preliminary research has shown some medicinal mushroom isolates to have cardiovascular, anticancer, antiviral, antibacterial, anti-parasitic, anti-inflammatory and anti-diabetic properties (Sullivan *et al*., 2006; Chang and Miles, 1989). Currently, several extracts (polysaccharides-K, polysaccharide peptide and lentinan) have widespread use in Japan, Korea and China, as potential adjuvants to radiation treatments and chemotherapy (Borchers *et al*., 2008; Sullivan *et al*., 2006).

Because there is no known test by which to tell if a mushroom is edible or not, a mushroom should never be eaten unless it has been accurately identified and the edibility of the species is known. Even though **poisonous mushrooms** represent less than 1% of the world's known mushrooms, we cannot ignore the existence of the relatively few dangerous and sometimes fatal species (Boa, 2004; Chang and Miles, 1989). Mushrooms must be identified by a competent mycological authority. Therefore, if one is not certain whether a given mushroom is edible or otherwise, it should not be picked. The toxins contained in various species are very different in chemical composition, and thus the effects of poisoning differ considerably according to the species involved. In any case, suspected mushroom poisoning should never be regarded lightly and immediate medical assistance should be sought (Chang and Miles, 1989).

All fungi possess hypha (plural: mycelium) that is located below the ground. The mycelium can remain dormant under the ground for many seasons, similar to the roots of plants. Each hypha that is sent out makes its way through earth/wood/plant matter until it reaches the surface (Goldin-Perschbacher, 2002)

During the organism's specific growing season, the hyphae develop into mature structures capable of reproducing spores. The structure that is normally seen above the ground is the part of the mushroom that is producing and dispersing spores (Goldin-Perschbacher, 2002).

Each spore is a single cell that is capable of sending out a hypha that will develop into a group and form its own mycelium. If the hypha of one spore meets up with the hypha of another, it begins the sexual process of spore production through special spore-producing cells (Oei, 2003; Goldin-Perschbacher, 2002)

There are two types of spore-producing cells: asci and basidia. In asci, the spores are fully contained within an outer covering. When the spores mature, the tip of the ascus breaks open and the spores are released. In basidia, the spores are produced externally. The spores are released when they break off. (In puffballs, the basidia are contained within an outer shell and the spores are released when the casing collapses.) (Oei, 2003; Goldin-Perschbacher, 2002)

When the spores of a mushroom are released, they may travel a certain distance before they land. The single cell then sends out hyphae to help establish the fungus and gather food.

After the spore has sent out its hyphae, they will eventually meet up with the hyphae of another mushroom. After the sexual process of reproduction has begun, the mushroom forms the structures of a "fruiting body" that will eventually produce and disperse spores. The egg/button stage is the early form of this fruiting body (Goldin-Perschbacher, 2002).

The mature fruiting body can have various structures. The fruiting body may contain a cap, stalk, ring, volva, and gills. The cap normally houses the spore producing surface of the fruiting body. In the case of the Amanita, the spore-producing cells are in the gills, but in other types of mushrooms, spores are produced in tubes or inside the cap (Oei, 2003; Goldin-Perschbacher, 2002)

Some mushrooms grow on a broad range of substrates while others are selective. Some Oyster mushrooms, for example, will grow on almost any broad-leaved tree wood as well as on straws, corncobs, and distillers grain waste, while Shiitake requires specific trees (or sawdust) to support its growth. The bulk substrate material for many mushrooms usually consists of agricultural waste with high ligno-cellulose content (Chang and Miles, 1989; Oei, 2003). Other nutrients may include sugars and proteins. Temperature for mushroom growth should be close to normal outside temperatures. Otherwise, expensive heating or cooling systems will be necessary. According to Oei (2003), the substrate temperature is an important parameter in both mycelial growth and fruiting body formation. A high substrate temperature (> 35°C), however, can trigger the thermophilic microflora leading to the killing of the mycelium of the cultivated mushroom. Oei (2003) opined that optimum relative humidity, carbon dioxide and light are ideal for mushroom growth. The higher the relative humidity the lower the temperature and the negative effect it has on the fruiting body. High $CO_2$ and light levels in the mushroom house cause elongation of stems and formation of small caps (Oei, 2003).

Under the right climatic conditions, the mycelium develops into small primordia, then into a fruiting body. The fruiting body consists of a cap and a stalk. It takes approximately about 15 days for a fruiting body to mature (Oei, 2003; Boa, 2004).

Besides the Oyster mushrooms that are cultivated by urban unemployed in Ghana, some species of wild mushrooms are harvested by rural folks during the onset of rainy seasons.

Notably among them are *Termitomyces* spp (Sibre/Aforti), *Volvariella volvacea* (Domo) *Coprinus* spp (Asasea), *Cantherellus aurantiacus* (Awiawi/Kofi Korku) with the words in parentheses indicating their traditional names (Obodai, 2001).These mushrooms are collected from the forests for home consumption and sold for extra income (Apetorgbor *et al*., 2005). Harvesting of wild mushroom by people is an old profession in many countries. For example, the British Columbia forests support a multi-million-dollar industry based on the commercial picking of edible wild mushrooms, many of which are exported to Japan and Europe (Ministry of Forest Range, 2014). In some of the British Columbia forests the mushroom crops are more valuable than the tree crops. The most common mushrooms picked for profit in the fall are the pine mushrooms (*Tricholoma magnivelare*), and chanterelles (*Cantharellus cibarius*); in the spring, the morels (*Morchella* species) are picked (Ministry of Forest Range, 2014).

Mushrooms are affected by all kinds of pests and diseases. Pests and diseases affect mushrooms in several ways: 1) by keeping the spawn from growing into the substrate; 2) by colonizing the substrate faster than the mycelium of the spawned mushroom; 3) damaging the mycelium of the spawned mushroom; and 4) by damaging the mushroom itself (Oei, 2003). Other factors such as poor strains, unsuitable substrates and unsuitable climatic conditions can adversely affect yield of the mushrooms (Oei, 2003). The organisms responsible for pests and diseases in mushroom cultivation include insects, termites, mites, nematodes, snails and rodents, parasitic fungi, saprophytic fungi, bacteria and viruses and the best way to fight these organisms is to prevent them (Oei, 2003). Strict hygienic measures and physical barriers are most important (Cha, 2004).

## 2.2 Nutrients Composition and Health Benefit of Mushrooms

Mushrooms are rich in non-starchy carbohydrates, proteins, dietary fibre, and vitamin-B and are quite low in fat value (Dunkwal *et al*., 2007). The dry matter of mushroom fruit bodies is about 5 – 15% and contains 19 – 35% proteins (Synytsya *et al*., 2008). The content of carbohydrates, which are mainly present as polysaccharides or glycoproteins, ranges 50 – 90%; chitin, α- and β-glucans and other hemicelluloses are in abundant in mushrooms (Synytsya *et al*., 2008). Edible mushrooms are good sources of vitamin B2, niacin and foliate, with contents varying in the ranges 1.8 – 5.1, 31 – 65 and 0.30 – 0.64mg/100g dry weight respectively (Mattila *et al*., 2001). Among the mushrooms, Shiitake has been identified as containing a good source of dietary fibre (3.3g/100g fresh weight); while *Agaricus bisporus* and *Pleurotus* spp contained 1.5-2.4g/100g fresh weight (Mattila *et al*., 2001). Compared with vegetables, mushrooms are a good source of many mineral elements. The contents of potassium, phosphorus, zinc and copper varied in the ranges 26.7 – 47.3g/kg, 8.7 – 13.9g/kg, 47 – 92mg/kg and 5.2 – 35mg/kg dw, respectively. *Agaricus bisporus* contain large amounts of Selenium (3.2mg/kg dw), while Cadmium content in shiitake mushrooms is quite high (1.2mg/kg dw) (Mattila *et al*., 2001). Apart from their nutritional value, mushrooms possess medicinal benefits (Chan, 1981). In China, 20 mushroom species have been documented by Li Shi-Zhen of having medicinal property and have been used for treating different kinds of diseases. Notably among these species are *Ganoderma lucidum, Poria cocos,* and *Tremella fuciformis* (Sullivan *et al*., 2006). Because of their low calorie value, intake of mushrooms by the obese help cut down their calorie level (Rai and Arumuganathan, 2008). Being low in fat, but desirable fat devoid of cholesterol, mushrooms are ideal diet for the heart patients. Mushrooms are high in protein with no starch and sugar and are therefore recommended for diabetic patients (Rai and Arumuganathan, 2008). Mushrooms contain anti-carcinogenic substances responsible for reducing and preventing the development and formation of cancer cells in humans (Bernaś and Jaworska, 2008). They enhance macrophage function and host resistance to microorganisms' infection (Lindequist *et al*., 2005). The presence of vitamins, minerals, and iron in addition to protein in the mushrooms help maintains haemoglobin level in humans thereby preventing anaemia (Rai and Arumuganathan, 2008). Rai and Arumuganathan (2008) reported that mushrooms are high in fibre and alkaline elements and are suitable for those suffering from hyperacidity and constipation. Many polysaccharide-bound proteins produced by Basidiomycetes fungi have been classified as anti-tumour chemicals by the US National Cancer Institute (Sullivan *et al*., 2006).

## 2.3 Harvesting and Processing of Mushrooms

Mushrooms form primordia (hyphal knots) within 10 days after spawning and are able to produce ready-to-pick fruit bodies within 15 days at an optimum temperature of about $23^{o}$ – $28^{o}$C (Oei, 2003). The stage at picking mushrooms depends on the consumer preference and the highest profitability. For oyster mushrooms, picking should be done when the outer margin of the fruiting bodies has only just rolled inwards, on the verge of becoming horizontal. Contrary, *Termitomyces* are picked when the veils are yet to open. In this way, the prize is higher and the infestation by nematode is reduced. Ideally, mushrooms should be picked with minimum handling since they are easily damaged (Oei, 2003). Harvesting is done by twisting the fruiting bodies from the substrate by hand, leaving no bits of stem behind. Oyster mushroom, for instance, can either be harvested in bundles or as single fruiting bodies. However, some species such as *Termitomyces* can only be harvested singly. After harvesting, mushrooms are either sold fresh or processed into different forms in a pack. Under ideal conditions, packed mushrooms for the fresh market are covered with a plastic film and cooled rapidly after harvesting (Oei, 2003). The plastic film provides good protection from water loss, as long as the storage temperature is more or less constant.

The taste and nutritional value of fresh mushrooms is usually better than that of conserved mushrooms. Nevertheless, conservation methods are necessary when only part of the harvest can be sold fresh. Canning, brining and drying are the most common techniques, but not all conservation methods are equally suitable for all different types of mushrooms (Oei, 2003; Byung, 2004). Canned oyster mushrooms, for instance, taste horrible except *Pleurotus cystidiosus* and *Pleurotus abalonus*. Contrary, oyster and shiitake mushrooms give off a specific fragrance after drying. The selection of the method for processing mushrooms depends, among other things, on the ultimate use of the products as well as on the storage period envisaged (Bernaś *et al*., 2006).

### 2.3.1 Drying

The oldest and simplest method of processing mushrooms is drying (Bernaś *et al*., 2006). Drying preserves the mushrooms by removing enough water to inactivate the enzymes and microorganisms (Byung, 2004). Fresh mushroom contains about 90% water and exposure of the product to temperatures of 55-70$^{o}$C for a number of hours to a final moisture content of 10% and below ensures that it does not deteriorate easily (Rai and Arumuganathan, 2008; Byung, 2004). However, longer drying at low temperatures is safer than faster drying on high heat, as the mushrooms could become toasted at high temperatures (Oei, 1996). According Oei (1996) drying of mushrooms could be artificial or sun drying. The disadvantages of sun drying are that: a) sand and dust decrease the quality and value of the product; b) there is an infestation by insect thereby making the product unsafe to eat. It is however recommended to spread the mushrooms on a platform above the ground (Oei, 1996). Drying whether artificial or natural has significant effect on the colour of the dried product due to the exposure to temperature, moisture of the mushroom and humidity of the air (Rai and Arumuganathan, 2008).

### 2.3.2 Freezing

Freezing is the best processing method for preserving the natural taste and aroma of mushrooms (Lobaszewski and Paczynska, 1990). According to Rai and Arumuganathan (2008) in order to preserve mushroom for about a year or more, the product must be freezed at a temperature of -18$^{o}$C and below. At this temperature, the growth of microorganisms, respiration and moisture loss from the mushrooms is minimized. In general, the nutritive value of frozen products exceeds that of sterilized food (Bernaś *et al.*, 2006).

### 2.3.3 Canning

Canning is by far the most common process used for preserving mushrooms (Byung, 2004). This technique can preserve mushrooms for longer periods up to a year or more (Rai and Arumuganathan, 2008). The process can be divided into various unit operations namely cleaning, blanching, filling, sterilization, cooling, labeling and packaging (Rai and Arumuganathan, 2008; Byung, 2004). Mushrooms must be canned in a pressure canner for the correct time and pressure to ensure their safety otherwise they may contain the deadly botulism toxin (Schafer, 2010). Pre-processing of mushrooms before sterilization plays an important role in maintaining good quality of canned products (Bernaś *et al*., 2006). The measures most frequently applied in preliminary processing are soaking and blanching in solutions preventing the darkening of the products (Rodrigo *et al*., 1999). Jaworska *et al*. (2003) reported that the addition of brine in the production of sterilized mushrooms decreases the dry matter by 26 – 28%, total sugars by 12 – 29%, total acids by 29 – 36% and total nitrogen by 24 – 29% as compared to raw material after blanching or after soaking followed by blanching. Galoburda *et al*. (2015) opined that blanching mushrooms at high temperature (100$^{o}$C) denatures protein. However, Vetter (2003) reported that this method of processing does not significantly affect the content of protein or fats in the mushroom but decreases the level of dry matter and ash and some mineral component such as potassium, phosphorus, magnesium and at the same time increases the content of sodium, calcium and iron. It is worth noting that the nutritional composition of any processed product depends on the quality of the raw material used in the production (Bernaś *et al*., 2006).

### 2.3.4 Pickling

Pickling mushrooms is a valuable processing method: it involves lactic bacteria, which have a beneficial effect on the human organism and impart a pleasant aroma and taste to the pickled food (Bernaś *et al*., 2006). Pickling is a long-term preservation of mushrooms in an economically viable way. The product produced after pickling is called pickle. These pickles are good appetizers and they add palatability to the meal (Rai and Arumuganathan, 2008). Mushrooms for pickling are blanched or fried in oil until they become brown depending upon taste preference. Various condiments are ground or fried in oil separately and added to the mushroom after which the contents are mixed and cooked slightly for few minutes. The mixture is allowed to cool and fill in jars. Vinegar is added for taste and longer storage and the container is topped up with oil (Rai and Arumuganathan, 2008).

## 2.4 Pests and Diseases of Mushroom

A wide range of diseases and pests can cause serious problems in mushroom cultivation, and management of those diseases and pests is a key factor in successful mushroom production (Cha, 2004). The main reasons for the existence of many diseases and pests problems in mushroom cultivation were due to the fact that: 1) Mushroom cultivation conditions such as high humidity and warm temperature are favored by many pathogens and pests; 2) There is a limit on chemical use for control of diseases or pests in mushroom cultivation; 3) Pathogens and pests are readily attracted inside and/or outside mushroom houses involved with continuous cultivation; and 4) Growing houses are not usually well equipped for environmental control (Cha, 2004). Common pests of mushrooms include mites, midges, millipedes and nematodes. They damage the fruiting bodies, attack the mycelium and tunnel through the stalk resulting in yield losses. Nematodes attack result in brown, watery mushrooms and in extreme cases, soggy, smelly compost. Even though the mushroom itself is a fungus, it can in turn be affected by a range of fungal pathogens such as *Dactylium, Fusarium, Mycogone, Papulaspora, Scopulariopsis, Trichoderma* and *Verticillium*. Apart from fungus diseases, bacteria and viruses attack mushroom as well. *Pseudomonas* is a bacterium that causes yellow to brown blotches on the cap, which may exude sticky residues. For any pest and disease management, sanitation and strict hygiene are the most important preventive methods for pest and disease control. Without them, effective disease or pest control will never be achieved. Every practice must focus on exclusion and elimination of pathogens or pests (Cha, 2004). Besides pest and disease management and control, timely processing and preservation of the mushrooms at storage temperature of 0-2℃ within five hours of picking stop metabolic process (Byung, 2004). Rai and Arumuganathan (2008) reported that mushroom after harvesting continue to grow, respire, mature, and senesce resulting in weight loss, veil-opening, browning, wilting and finally deteriorate. Improper and untimely harvesting increase pests and diseases attack of the mushroom (Santosh *et al*., 2014). Some common pests and diseases of mushrooms have been discussed below.

### 2.4.1 Pests of Mushrooms

#### *2.4.1.1 Sciarids*

These are the main mushroom pests. Larvae kill pinheads and pea-sized mushrooms, and tunnel in stalks and caps. Adults are the main culprits in disease spread. They are small black flies longer than phorids, broad and have long antennae. They are attracted to compost for egg laying immediately after cool-down and throughout the life of the crop. Larvae have a distinct black head and their gut contents can be seen through their body wall (Staunton and Dunne, 1999).

A generation takes about 5 weeks to turn over so that eggs laid early in the spawn run give rise to adults at about the first flush. It is the offspring of these that do most damage. Sciarids are mainly inhabitants of the casing, where they do most damage (Staunton and Dunne, 1999; Phillip, 2002).

The key to good sciarid control is exclusion during spawn run by having well sealed growing tunnels (Staunton and Dunne, 1999; Phillip, 2002).

#### *2.4.1.2 Phorids*

Adult's phorids are much smaller and shorter than sciarids and tend to fly less. They are actively attracted (often from considerable distances) to compost or casing in which spawn is running. The life cycle takes 2 weeks at 25°C and 5 weeks at 18°C. Consequently eggs laid early in the spawn run give rise to adults soon after casing and these reproduce again to give very high populations of adults 4-5 weeks into cropping (Staunton and Dunne, 1999).

The adult flies are not as significant in disease spread as sciarids but are a great nuisance to pickers. Larvae are pointed at one end and blunt at the other. They do not have a black head. They feed on mushroom mycelium. The key to efficient phorid control is exclusion during spawn run (Staunton and Dunne, 1999; Phillip, 2002).

#### *2.4.1.3 Cecids*

Cecids are unusual in that mature larvae regularly split to give many daughter larvae thereby dispensing with the adult stage in the interests of rapid population increase. This means that they have the potential to reach huge numbers in a short time and the consequence of this is large-scale contamination of mushrooms, bags etc. and easy spread between crops. Larvae also carry bacteria that cause browning of the stalks of mushrooms. Adults are rarely seen. Larvae live mostly in compost and suck the contents from mushroom mycelium (Staunton and Dunne, 1999; Phillip, 2002).

### *2.4.1.4 Tarsonemid mites*

These invisible microscopic mites can occur in vast numbers in crops and their feeding causes reddish-brown discoloration of the base of the stem. Badly anchored and off-colour mushrooms are also symptoms of their feeding on mycelium. The key to their control is good between-crop hygiene (Staunton and Dunne, 1999; Phillip, 2002).

### *2.4.1.5 Pepper mites*

These minute brownish mites sometimes swarm in huge numbers on the casing surface and mushrooms. They do not feed on mushroom mycelium but on weed moulds particularly green mould, their occurrence being a symptom of its presence. The huge numbers disappear after a few days and there is no yield loss (Staunton and Dunne, 1999; Phillip, 2002).

### *2.4.1.6 Predatory mites*

Robber mites (*Parasitus* sp) can occur in large numbers. They are predators of the other small organisms' present e.g. fly larvae, mites, eelworms. They can reach numbers that annoy pickers. Long legged mites (*Linopodes* sp) behave similarly. These are beneficial mites as they are natural enemies of mushroom pests. *Parasitus* has been used experimentally at Kinsealy to control sciarids (Staunton and Dunne, 1999; Phillip, 2002).

#### *2.4.1.7 Eelworms*

Rhabditid nematodes or eelworms are bacterial feeders and their presence on the surface of compost or casing indicates some deficiency in the compost, which has resulted in bacterial decomposition. As they do not feed on mycelium, their presence does not necessarily result in yield loss (Staunton and Dunne, 1999; Phillip, 2002).

### 2.4.2 Diseases of Mushrooms

#### *2.4.2.1 Verticillium Diseases*

*Verticillium* is one of the most significant diseases of commercial *Agaricus* production. It is endemic on many mushroom farms and can cause substantial yield reduction. It can occur in nature in addition to cycling within a mushroom farm, traveling from older to newer growing rooms. Symptom of the disease include small spotting on the surface of a mushroom cap to a complete infection of the fruiting body. The spot area of the mushroom infected by the fungus remain stunted while the uninfected part grow well (Phillip, 2002).

#### *2.4.2.2 Trichoderma Green Mold*

*Trichoderma harzianum* is a relatively new disease of commercial mushroom production. Aggressive strains of *Trichoderma harzianum* have been associated with the commercial production of *Agaricus bisporus*. *Trichoderma* species are asexual fungi that propagate through vegetative growth and production of asexual spores (conidia). They can also reproduce by sexual means. *Trichoderma* mycelium grows on compost and competes aggressively with mushroom mycelium. *Trichoderma* mycelium is gray in the beginning and then changes to white, becoming very dense. After fruiting, its spores turn it a dark green (Phillip, 2002).

#### *2.4.2.3 Dactylium Diseases*

*Dactylium* mildew, or cobweb mold, can be recognized by its wefty, cotton-like mycelium. The mycelium will cover the surface of the casing as well as the surface of mushrooms and mushroom pins. The mycelium is usually white, but can be gray and often turns pink or yellow with age. Infected mushrooms develop a soft, wet rot.

Cobweb mold is a relatively minor disease of mushrooms, but because of its ability to grow quickly, it can spread over many mushrooms. If left unchecked, widespread mildew can result in unsalable mushrooms and eventual significant yield loss (Phillip, 2002).

## 2.5 The Wild Mushroom (*Termitomyces* spp)

Termites are found mostly in the tropics, some in temperate zones and very few in the cooler climates. With about 2600 species worldwide they are probably the dominant organism in tropical forest environments (Gover, 2008). One subfamily, the Macrotermitinae Termites consume plant material, construct “combs” with their excreted ‘pseudofaeces’ and inoculated with the spores of an exosymbiont fungus, *Termitomyces* species (Harkonen *et al*., 2003; Bobby *et al*., 2011). The fungus grows on the combs and produces nutritious fungal compost containing a variety of energetically expensive nitrogen compounds that is consumed by the termites (Gover, 2008). The fungal comb is a kind of extracorporeal digester to which the termites have ‘outsourced’ cellulose and lignin digestion. The fungus-enriched food allows the termite colony to mobilize energy at faster rates and are not limited by the bacterial endosymbionts of most other species of termite. According to Gover (2008); Bobby *et al*. (2011), a mature colony will have a total of about 40 kg of fungal combs, each comb located in a semi-enclosed gallery around the periphery of the aboveground mound nest and when the rains arrive, the fungus, *Termitomyces* produces mushrooms that penetrate the nest and emerge above ground. The edible and nutritious mushrooms are highly prized as a delicacy and contribute to the local economy.

There are more than 60 *Termitomyces* taxa described, but reliably only 18 species, collected mainly from West Africa, are reasonably well known, the rest are either synonyms or badly described and difficult to identify. A genus, *Sinotermitomyces* has been reported from China, but species are difficult to classify (Gover, 2008). Characteristically, *Termitomyces* has pinkish spores, a cap and stipe at the top of a long ‘pseudorhiza’ that arises from the comb and the cap has a ‘perforatorium’ or ‘umbo’ that assists the mushroom to penetrate the hard ground and there is a termite association.

# CHAPTER THREE

## 3.0 MATERIALS AND METHODS

### 3.1 Survey to assess farmers' methods of reducing postharvest losses of wild mushrooms in the Kpelezo community in the Volta Region of Ghana

The survey was conducted between November and December, 2014 to obtain baseline data on farmers' knowledge on methods of harvesting, postharvest management and ways of reducing postharvest losses of wild mushrooms in the Kpelezo community in the Volta Region of Ghana. Fifty farmers (50) were randomly selected from the community for the survey. Pre-tested semi-structured questionnaires were read to the farmers by trained enumerators and their responses recorded. Details of questionnaire items administered are shown in Appendix 1.

### 3.2 Determination of optimum conditions for drying mushrooms

Two fresh mushroom varieties, *Pleurotus ostreatus* and *Termitomyces* spp were purchased from two farmers at Hohoe and Kpelezo and kept in separately covered plastic containers. The mushrooms were transported the same day to Noguchi Memorial Research Institute, University of Ghana for analysis. The mushrooms were washed under running tap water to remove soil particles and cut into small pieces. They were kept in plastic containers and stored in a refrigerator at $0^{o}C$.

### 3.2.1 Pretreatment

**Pretreatment**

The two varieties of fresh mushroom were sliced into small pieces with knife. 1000g of each mushroom variety was weighed for each treatment, making a total weight of 8000g for the two varieties. Each variety was subjected to two pretreatments, namely, blanching and grilling prior to the actual dehydration. Blanching was done by dipping the mushrooms in hot brine solution at 100$^{o}$C for 15 minutes. This solution contained 20g of sodium chloride dissolved in 500ml of water. Grilling was done by spreading the mushrooms on wire mesh and placed over burning charcoal. The mushrooms were turned periodically for 15 minutes. For the 4 treatments used, each sample was dried from an initial moisture content of 80 – 85 percent on fresh weight basis to the final moisture content of 10 percent on dry weight basis. The treatments and drying methods employed were done according to the procedure proposed by Rai and Arumuganathan (2008).

### 3.2.2 Sun Drying

The two varieties of the mushroom were spread on two separate porcelain trays and sun dried. The atmospheric temperature during the 7 days drying period ranged between 30 – 33$^{o}$C and relative humidity ranged from 65 – 70 percent.

### 3.2.3 Mud Oven Drying

The two varieties of the mushroom were spread on stainless steel trays and kept in a mud oven at 80$^{o}$C for 2 hours. The samples were removed from the oven and allowed to cool at room temperature.

### 3.2.4 Packaging

Two types of packaging material, rubber bag and plastic container, were used. The dried samples were packaged in these materials for proximate analysis at days 0, 10 and 20.

### 3.2.5 Storage Procedure

The dried *Termitomyces* spp was divided into 2 main parts. Each part was sub-divided into 8, giving a total of 16. The same procedure was used to divide the *Pleurotus ostreatus*. Four processing techniques were used such that each species was packaged in 4 rubber bags and 4 plastic containers. This resulted in having 4 rubber bags and 4 plastic containers packages for each species under each storage condition. Since 2 storage conditions (i.e. storing at 4$^{o}$C and 30 – 33$^{o}$C) were employed, 16 samples (8 for each species), in each storage condition were used. The entire storage duration was 20 days. 10 days storage intervals were allowed before the samples were analyzed for proximate composition. The composition analysis was repeated after another 10 days storage intervals.

## 3.3 Proximate Analysis

### 3.3.1 Determination of Protein

#### *3.3.1.1 Digestion*

Five grams each of the dried mushrooms samples was weighed into a digestion flask and digested by heating in the presence of concentrated sulphuric acid and catalysts (copper sulphate and potassium sulphate at a ratio of 1:10). The digestion converts nitrogenous compound into ammonium sulphate, and other organic matter to carbon dioxide ($CO_2$) and water ($H_2O$). Ammonia gas is not liberated in an acid solution because the ammonia is in the form of the ammonium ion ($NH_4^+$) which binds to the sulphate ion ($SO_4^{2-}$) to form $(NH_4)_2SO_4$.

### *3.3.1.2 Neutralization*

After the digestion was completed, the digestion flask was connected to a receiving flask by a tube. The solution in the digestion flask was made alkaline by the addition of concentrated sodium hydroxide, which converts the ammonium sulphate into ammonia gas. The ammonia gas formed was liberated from the solution and removed into the receiving flask – which contained an excess of $H_2SO_4$. The low pH of the solution in the receiving flask converts the ammonia gas into the ammonium ion, and $H_2SO_4$ to the sulphate ion.

### *3.3.1.3 Titration*

The nitrogen content was estimated by titration of the ammonium sulphate formed with standard sulphuric acid, using a suitable indicator to determine the end-point of the reaction.

The concentration of hydrogen ions (in moles) required to reach the end-point is equivalent to the concentration of nitrogen that was in the mushrooms. The nitrogen content in the food was determined using the equation below:

$$\%N = \frac{H_2SO_4\ Vol. - NaOH\ Vol. \times \left(Normality\ of\ \ H_2SO_4\right) \times 14100}{Wt\ of\ \ sample\ in\ mg}$$

The nitrogen content was converted to protein content by multiplying with a conversion factor of 6.25. That is $\%Protein = \%N \times 6.25$

### 3.3.2 Determination of Moisture Content in Mushrooms

An empty dish was weighed and 2g of the mushrooms was weighed into the dish and placed in a hot air oven for 24 hours at a temperature of 105$^{o}$C. The sample was allowed to cool in a desiccator and reweighed to obtain the differences in weight. The percentage moisture loss was calculated as follows:

$$Wt\ of\ empty\ dish = a$$

$$Wt\ of\ dish + sample\ before\ drying = b$$

$$Wt\ of\ dish + sample\ after\ drying = c$$

*Cal.*

$$Initial\ weight = b - a$$

$$Final\ weight = c - a$$

$$\%Moisture = \frac{Initial\ weight - Final\ weight}{Initial\ weight}\ x\,100\%$$

### 3.3.3 Determination of Ash in Mushrooms

An empty crucible was weighed and 2g of the mushrooms was weighed into the crucible. The samples were placed into an Ikemoto 7182 Automatic Muffle Furnace at temperature of 600$^{o}$C for 1 hour. The crucibles were removed, covered and allowed to cool at room temperature. The crucibles and the ash were weighed repeatedly to obtain near to constant weight. The percentage ash was calculated from the data obtained as follows:

$Wt\ of\ \ empty\ crucible = a$

$Wt\ of\ \ crucible + sample\ before\ ashing = b$

$Wt\ of\ \ crucible + sample\ after\ ashing = c$

$Cal.$

$Initial\ \ weight = b - a$

$Final\ \ weight = c - a$

$$\%Ash = \frac{Initial\ \ weight - Final\ \ weight}{Initial\ \ weight}\ x\,100\%$$

### 3.3.4 Determination of Ascorbic Acid in Mushrooms

Two grams (2g) of mushroom powder was ground with 20 ml of 0.4% oxalic acid for 5 minutes and filtered. Five millilitres (5ml) of the filtrate was titrated against blue dye 2:6 dichlorophenol indophenol and the titre value noted. This was duplicated to obtain two more titre values. Based on the results, the ascorbic acid in 2g of the mushrooms was calculated. For example:

$If\ \ 1ml\ \ dye = 0.21mg\ \ ascorbic\ \ acid$

$Then\ 0.5ml\ \ dye = x$

$x = 0.5 \times 0.21 = 0.105mg$

### 3.3.5 Determination of Fat in Mushrooms

Two grams (2g) of the mushroom sample was weighed into the thimbles. The thimbles were plugged lightly with cotton wool, slipped into the thimble holders and clipped into position in the extraction chamber. Forty millilitres (40 ml) of diethyl ether was added to each chamber to ensure that the sample in the thimbles was completely covered by the solvent. A rubber tube was connected to a running tap to allow water to circulate through the extractor to condense the evaporated ether. The still pots of the extractor were placed on the heaters and the switches of heaters were turned on. The heat generated by the still pots caused the ether in the extraction chamber to boil. The boiling allowed all fats in the mushrooms to dissolve into the ether. Approximately, 40 minutes were allowed between each extraction. The knobs beneath the extraction chambers were turned to drain the ether in the extraction chambers for the next extraction. The thimbles were removed and dried in a desiccator. The thimble and the sample were weighed to determine the amount of fat extracted as follows:

$$Wt\ of\ empty\ thimble = a$$

$$Wt\ of\ thimble + sample = b$$

$$Wt\ of\ thimble + sample + cotton\ (before\ extraction) = c$$

$$Wt\ of\ thimble + sample + cotton\ (after\ extraction) = d$$

$$Cal.$$

$$Wt\ of\ sample = b - a = x$$

$$Wt\ of\ fat = c - d = y$$

$$\%Fat = \frac{y}{x} \times 100$$

### 3.3.6 Determination of Carbohydrate and Calories in Mushrooms

The following formulae prescribed by Journal of AOAC International (2000) were used for the calculation of Carbohydrate and Calories.

$$Carbohydrate = Solids - (Protein + Fat + Ash)$$

$$Calories\ (Kcal.) = 9\ (Fat) + 4\ (Protein) + 4\ (Carbohydrate)$$

### 3.3.7 Determination of Minerals in Mushrooms

#### *3.3.7.1 Digestion of samples for mineral analysis*

Dry mushroom sample (0.1g) was weighed into a clean dry 125ml ‘pyrex’ conical flask. Four millilitres (4ml) concentrated sulphuric acid ($H_2SO_4$) was added and the flask was swirled carefully to ensure that the acid react with the sample to change it to carbon. The flask (and contents) was heated in a fume hood on an electric hot plate set at “medium” heating (125$^oC$) for 1 hour. Ten drops of hydrogen peroxide ($H_2O_2$) was added: adding 3-4 drops slowly at a time to avoid vigorous reaction of the contents. The flask was swirled, keeping the contents at the bottom of the flask and reheated but avoiding excessive heating that causes spattering. Six drops of $H_2O_2$ was carefully added and the flask was reheated. Addition of 6 drops of $H_2O_2$ continued until the colour changed from black to dark brown. The burner temperature was increased to 350$^oC$ on the hot plate while heating continued. Six (6) drops of $H_2O_2$ were again added to the mixture while heating of the flask continued. When the solution stayed colourless from heating, 6 drops of hydrogen peroxide were added and then left for the last time on ‘high’ burner for 10 – 15 minutes. The colourless solution obtained was an indication that the carbon had changed to carbon dioxide. The content was finally cooled and transferred quantitatively into a

100ml volumetric flask using distilled water. The solution was later brought up to the 100ml mark of the volumetric flask. Besides, 2 blank digests of the same amounts of reagents ($H_2SO_4$ and $H_2O_2$) were prepared and all data against mean blank value was corrected. The calcium and zinc values in the mushrooms were determined using Atomic Absorption Spectrophotometer (AAS). For phosphorus, its colour in the sample was developed and read with Pharo 300 Spectrophotometer at a wavelength of 712nm.

#### *3.3.7.2 Colour Development of Phosphorus*

##### *3.3.7.2.1 Preparation of the Solutions*

One hundred and forty millilitres (140ml) of concentrated $H_2SO_4$ was carefully added to 500ml of distilled water and the solution was allowed to cool. 12g of Ammonium Molybdate was dissolved in 150ml of distilled water. 0.2908g of Antimony Potassium Tartrate was also dissolved in 100ml of distilled water. All the solutions were carefully added together and made up to 2 litres to obtain a stock solution. 1.056g of L-Ascorbic Acid was weighed, dissolved in the stock solution and made up to 200ml using the stock solution. 0.878g of Potassium Dihydrogen Orthophosphate was dissolved in 1 litre distilled water. The stock solution (Potassium Dihydrogen Orthophosphate solution) was used to prepare standards for calibration of Pharo 300 Spectrophotometer. For calibration, 25ml of the stock solution was diluted to 1 litre. Every 1ml of this solution pipetted contained 5µg P; 2ml contained 10µg P; 3ml contained 15µg P; etc. A graph of concentration was plotted against absorbance to finish the calibration procedures.

#### *3.3.7.2.2 Procedure for Colour Development and Phosphorus Determination*

Thirty millilitres (30ml) of distilled water was added to 1ml of pipetted sample solution or digested sample solution. A drop of P-nitrophenol and one or few drops of ammonium solution (the drops are dependent on the concentration of the phosphorus in the sample) was added to turn the colour yellow. 8ml of L-Ascorbic Acid was added to the solution and at least 10 minutes (but not more than 30 minutes) was allowed for the colour to turn blue. The volume was made up to the 50ml mark with distilled water and read on the Spectrophotometer at 712 wavelengths.

### *3.3.7.3 Determination of Calcium and Zinc*

Calcium and Zinc were determined using a Perkin Elmer Analyst 400 Atomic Absorption Spectrophotometer (AAS) at the Ecological Laboratory, Department of Geography and Resource Department, University of Ghana, Legon. The instrument was calibrated with known standards. Standard stock solutions of 1000mg/L (1000ppm) were used. From the stock solution of each element, working standard solutions of 0.4ppm, 1ppm and 2ppm were used to plot a graph of concentration against absorbance. After calibration, the solution resulting from the digestion of the samples described above was sucked into the flame of the atomic absorption apparatus. The concentration of the metals (the unknown) to be analyzed in the mushrooms was measured at a specific wavelength in the AAS.

The specification readings of Atomic Absorption Spectrophotometer were calculated using the formulae below:

$$\%\ Zn\ or\ Ca = \left(\frac{AAS\ Red.}{1000}\right) \times \left(\frac{VExt}{1000}\right) \times \left(\frac{100}{Wt}\right)$$

$$\%P = \left(\frac{Spec\ Red}{Wt}\right) \times \left(\frac{VExt}{Aliquot}\right) \times \left(\frac{100}{10^6}\right)$$

VExt = Volume of extract i.e. the vol. of solution extracted from 2g of ash sample.

Aliquot = Part of the volume used for determination of minerals in the sample

AAS Red = Atomic Absorption Spectrophotometer Reading

Spec Reading = Spectrophotometer Reading

Wt = Weight of ash taken

## 3.4 Consumer Evaluation

Sensory properties for the four dried mushrooms were evaluated by 50 untrained panelists from the Kpelezo community. Product evaluation was done to obtain subjective data (how well the product is likely to be accepted) from the community.

The panelists observed the mushrooms displayed and rated them based on appearance (colour, size, shape and surface texture), odour/aroma, taste, flavour and texture using the questionnaire provided to them (Appendix 8).

Score sheets were presented to each participant and the parameters for the four samples were recorded using table of scoring (see Appendix 9).

# CHAPTER FOUR

# 4.0 RESULTS

## 4.1 Farmers' methods of harvesting wild mushroom, postharvest management and ways of reducing postharvest losses of wild mushrooms

The questionnaire was administered to mushroom farmers in the Kpelezo community in the Volta Region to obtain baseline information on farmers' method of harvesting wild mushrooms, postharvest management and ways of reducing postharvest losses of wild mushrooms. The data obtained from the survey are shown below.

### *4.1.1 General background of wild mushroom collectors*

Greater number of wild mushrooms collectors in the Kpelezo community in the Volta Region were males (54%) and (46%) were females (Table 4.1). Their main occupation were farming (54%), students (26%), artisans (12%), traders (6%) and animal rearers (2%). For secondary occupation, 76% are into wild mushrooms harvesting, 8% rear animals and harvest wild mushroom, 6% are petty traders, another 6% refine palm oil, 2% are into security and 2% weave baskets (Table 4.1).

Table 4.1: Demographic characteristics

| Characteristics | Category | Percentage value (%) |
|---|---|---|
| Sex | Female | 46.0 |
| | Male | 54.0 |
| Main occupation | Farming | 54.0 |
| | Students | 26.0 |
| | Artisans | 12.0 |
| | Animal rearing | 2.0 |
| | Business/trading | 6.0 |
| Secondary occupation | Petty trading | 6.0 |
| | Harvesting wild mushroom | 76.0 |
| | Palm oil refinery | 6.0 |
| | Animal rearing & harvesting mushroom | 8.0 |
| | Security | 2.0 |
| | Basket weaving | 2.0 |

### *4.1.2 Method of harvesting wild mushroom*

Sixty-six percent (66%) of mushroom farmers harvest wild mushrooms when the veil was not opened, 32% harvest when the veil was about to open and 2% harvest when the veil was opened. Ninety percent (90%) of farmers harvest mushrooms in the morning and 10% harvest in the afternoon. Eighty-seven percent (87%) harvest mushrooms by pulling them with hand and 14% by digging around them with cutlass before pulling them with hands (Table 4.2).

Table 4.2: Harvesting of wild mushrooms

| Characteristics | Category | Percentage value (%) |
|---|---|---|
| Ideal stage for harvesting | When the veil has not open | 66.0 |
| | When the veil is about to open | 32.0 |
| | When the veil has open | 2.0 |
| Ideal time for harvesting | Early in the morning | 90.0 |
| | Afternoon | 10.0 |
| How mushrooms are harvested | Pulling them with hands | 86.0 |
| | Digging around them with cutlass & pulling | 14.0 |
| Amount of mushroom collected per day | 2.0 kg | 2.0 |
| | 3.0 kg | 30.0 |
| | 4.0 kg | 26.0 |
| | 5.5 kg or more | 42.0 |

#### *4.1.3 Postharvest management of wild mushroom*

Forty-six percent (46%) of farmers kept harvested wild mushrooms in open bowls from the farm to their houses. Thirty-four percent (34%) kept them in covered bowl, 12% in tied sacks and 8% tied them together and held them with hands. None of the farmers pretreated mushrooms before sale. All farmers packaged fresh mushrooms by tying them into bunches with threads and displayed them at the roadside. Fresh mushrooms that were not sold during the day were treated differently by farmers. Fifty-two percent (52%) of the farmers baked and sun dried fresh mushrooms that were unsold. Thirty-two percent (32%) of them dip mushrooms in salt solution before drying. Furthermore, 12% of them grilled the mushrooms while 2% sun dried them. Two percent (2%) of the farmers steamed the unsold mushrooms (Table 4.3).

Table 4.3: Postharvest handling of wild mushrooms

| Characteristics | Category | Percentage value (%) |
|---|---|---|
| Mushroom handling after harvest | Kept in an open bowl | 46.0 |
| | Kept in a bowl and covered | 34.0 |
| | Tied with thread | 8.0 |
| | Tied and kept in a sack | 12.0 |
| Handling of mushroom when unsold | Baking and sun drying them | 52.0 |
| | Dipping in salt soln. & drying them | 32.0 |
| | Grilling them | 16.0 |
| Volume of mushroom sold daily | 1.0 kg | 6.0 |
| | 2.0 kg | 24.0 |
| | 3.0 kg | 42.0 |
| | 4.0 kg | 24.0 |
| | 5.0 kg or more | 4.0 |
| Major causes of loss in mushroom | Pest attack | 98.0 |
| | Disease attack | 2.0 |
| Reduction of cap/ stalk loss | Holding stalk and gently pulling | 10.0 |
| | Digging soil around and pulling them | 37.0 |
| | Proper handling mushroom | 22.0 |
| | Handling with care and tying them | 31.0 |
| Ways to minimize loss in mushroom harvested | Grilling and sun drying | 30.0 |
| | Keeping in refrigerator | 6.0 |
| | Baking and sun drying | 46.0 |
| | Soaking in salt soln. & sun drying | 10.0 |
| | Dipping in brine soln. & sun drying | 8.0 |

### *4.1.4 Ways of reducing postharvest losses of wild mushrooms*

It was observed that collectors/farmers sold only about 60% of mushrooms collected per day (Table 4.3). 98% of postharvest losses of wild mushrooms were observed to be caused by pests and the remaining 2% by diseases. 37% of the farmers suggested that postharvest losses of mushroom can be minimized by digging the soil around the mushrooms before pulling them with hands. 31% of the farmers were of the view that losses can be minimized by handling mushrooms with care and tying them up with threads. 22% of farmers were of the opinion that proper handling of mushrooms after harvesting can reduce losses. However, 10% of the farmers suggested holding the stalk and gently pulling the mushrooms to prevent losses (Table 4.3).

## 4.2 Proximate composition analysis

The fresh mushroom samples for the two varieties after washing were subjected to proximate composition analysis. The analysis was done to ascertain the nutritional composition prior to processing. The values for this analysis was displayed in Table 4.4.

*Termitomyces* spp had higher compositions of protein (2.095%), carbohydrate (8.304%) and fat (8.124%) than the same nutrient values of 0.858%, 7.358% and 6.333% obtained for *Pleurotus ostreatus*. The ash (0.603%) and energy (114.712 Kcal.) values were also higher in *Termitomyces* spp than 0.584% and 89.861 Kcal. recorded for *Pleurotus ostreatus*. Contrary, *Pleurotus ostreatus* had higher moisture (84.867%) and phosphorus (0.460%) values than 80.874% and 0.346% obtained for *Termitomyces* spp. However, the two varieties had similar ascorbic acid values (0.015mg/ml). *Pleurotus ostreatus* had some amount of calcium (0.003%) whilst *Termitomyces* spp had none (Table 4.4).

Table 4.4: Proximate composition of cultivated and wild fresh mushrooms (per 100g sample)

| Mushroom species | Moisture | Protein | Carbo-hydrate | Fat | Ascorbic acid (mg/ml) | Zinc | Calcium | Phos-phorus | Ash | Energy (Kcal.) |
|---|---|---|---|---|---|---|---|---|---|---|
| *Termitomyces species* | 80.874 | 2.095 | 8.304 | 8.124 | 0.015 | 0.038 | ND | 0.346 | 0.603 | 114.712 |
| *Pleurotus ostreatus* | 84.867 | 0.858 | 7.358 | 6.333 | 0.015 | 0.037 | 0.003 | 0.460 | 0.584 | 89.861 |
| **LSD (5%)** | **0.0264** | **0.0464** | **0.2749** | **0.0442** | **NS** | **NS** | **NS** | **0.0154** | **0.0019** | **0.01248** |

*ND – Not Detected*
*NS – Not Significant*
*Values are expressed on wet weight basis*

Figure 4.1: Baked & Dried Oyster Mushroom

Figure 4.2: Sun Dried *Termitomyces* spp

Figure 4.3: Mud Oven Dried *T.* spp

Figure 4.4: Blanched & Dried *T.* spp

The appearances of the dried mushroom samples are displayed in Figures 4.1 – 4.4.

Proximate composition analysis on the dried samples was carried out and the results are shown in Table 4.5. There were significant differences ($p < 0.05$) among all the treatments. Sun dried *Termitomyces* spp had the highest moisture value (16.034%) while baked and sun dried oyster mushroom had the lowest (3.522%). The protein value (20.804%) was significantly higher in mud oven dried *Termitomyces* spp and lowest (1.733%) in blanched and sun dried oyster mushroom. For carbohydrate, baked and sun dried *Termitomyces* spp had the highest value (73.022%) while baked and sun dried oyster mushroom had the lowest (57.480%). A different trend was observed in the fat content of the two varieties. Baked and sun dried oyster mushroom recorded the highest fat value (12.646%) while blanched and sun dried oyster mushroom had the lowest (0.045%). Mud oven dried oyster mushroom had the highest ascorbic acid value (0.546mg/ml) while blanched and sun dried oyster mushroom had the lowest (0.063mg/ml). It was observed that mud oven dried oyster mushroom had the highest zinc value of 0.054% while blanched and sun dried *Termitomyces* spp had the lowest value of 0.033%. Regarding calcium, blanched and sun dried *Termitomyces* spp had the highest (0.037%) while mud oven dried oyster mushroom had the lowest (0.004%). However, calcium was not detected in sun dried *Termitomyces* spp; mud oven dried *Termitomyces* spp; baked and sun dried oyster mushroom; and blanched and sun dried oyster mushroom (Table 4.5). Phosphorus value was higher in mud oven dried *Termitomyces* spp (0.806mg/g) and lowest in blanched and sun dried *Termitomyces* spp (0.257mg/g). The ash value was found to be higher in blanched and sun dried oyster mushroom (15.092%) and lowest in baked and sun dried *Termitomyces* spp (3.660%). The energy values ranged from 282.253 Kcal to 402.646 Kcal. Blanched and sun dried oyster mushroom had the lowest while baked and sun dried oyster mushroom had the highest (Table 4.5).

Table 4.5: Proximate composition of processed mushrooms (per 100 g sample)

| **Sample** | **Treat-ment** | **Moisture** | **Protein** | **Carbo-hydrate** | **Fat** | **Ascorbic acid(mg/ml)** | **Zinc** | **Calcium** | **Phos-phorus** | **Ash** | **Energy (Kcal.)** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Termito-myces | Sun dried | **16.034** | 11.256 | 64.591 | 3.597 | 0.168 | 0.044 | ND | 0.498 | 4.522 | 335.761 |
| | Baked & dried | 13.371 | 5.567 | **73.022** | 4.380 | 0.126 | 0.042 | 0.008 | 0.436 | 3.660 | 353.776 |
| | Blanched & dried | 11.942 | 6.219 | 58.134 | 9.628 | 0.084 | 0.033 | **0.037** | 0.257 | 14.077 | 344.028 |
| | Mud oven dried | 12.324 | **20.804** | 57.890 | 4.566 | 0.231 | 0.041 | ND | **0.806** | 4.416 | 355.870 |
| Oyster mushroom | Sun dried | 12.656 | 19.839 | 57.716 | 4.582 | 0.105 | 0.041 | 0.006 | 0.533 | 5.207 | 351.458 |
| | Baked & dried | 3.522 | 14.728 | 57.480 | **12.646** | 0.126 | 0.039 | ND | 0.721 | 4.580 | **402.646** |
| | Blanched & dried | 14.401 | 1.733 | 68.729 | 0.045 | 0.063 | 0.042 | ND | 0.392 | **15.092** | 282.253 |
| | Mud oven dried | 11.414 | 18.306 | 60.102 | 4.457 | **0.546** | **0.054** | 0.004 | 0.410 | 5.721 | 353.745 |
| | LSD (5%) | **0.0044** | **0.0017** | **0.0018** | **0.0017** | **0.0017** | **0.0017** | **0.0009** | **0.0017** | **0.0017** | **0.0017** |

*Values are expressed on dry weight basis*
*ND – Not Detected*

The samples were packaged in rubber bags and plastic containers after drying and kept in a refrigerator (4$^{o}$C) and room temperature (30 – 33$^{o}$C) for 10 days. Proximate composition analysis was carried out at 10 days intervals to ascertain changes in nutritional composition. The results are shown in tables 4.6 and 4.7.

There were significant differences ($p < 0.05$) among all the treatments. However, after 10 days of storage, mud oven dried *Termitomyces* spp packaged in rubber bag had the highest moisture content (2.825%) while blanched and sun dried oyster mushroom packaged in rubber bag had the least (0.599%). Mud oven dried oyster mushroom packaged in plastic container had the highest percentage protein (23.526%) compared to all the treatments while baked and sun dried *Termitomyces* spp packaged in rubber bag had the least (7.873%). Baked and sun dried *Termitomyces* spp packaged in rubber bag had the highest amount of carbohydrate (80.761%) while blanched and sun dried *Termitomyces* spp packaged in plastic container had the lowest (54.453%). Sun dried *Termitomyces* spp packaged in rubber bag had the highest amount of fat (7.620%) while blanched and sun dried oyster mushroom packaged in plastic container had the lowest amount of fat (0.100%). Mud oven dried oyster mushroom packaged in plastic container had the highest ascorbic acid value (0.430mg/ml) while blanched and sun dried oyster mushroom packaged in rubber bag had the lowest ascorbic acid value (0.060mg/ml). Mud oven dried *Termitomyces* spp packaged in plastic container; baked and sun dried oyster mushroom packaged in rubber bag; mud oven dried oyster mushroom packaged in rubber bag; baked and sun dried oyster mushroom packaged in plastic container; and mud oven dried oyster mushroom packaged in plastic container had the highest but similar amount of zinc (0.003%) while baked and sun dried *Termitomyces* spp packaged in rubber bag;

blanched and sun dried *Termitomyces* spp packaged in rubber bag; baked and sun dried *Termitomyces* spp packaged in plastic container; and blanched and sun dried *Termitomyces* spp packaged in plastic container had the lowest but similar amount of zinc (0.001%). Blanched and sun dried oyster mushroom packaged in rubber bag and mud oven dried oyster mushroom packaged in rubber bag had the highest but similar calcium values (0.006%) while blanched and sun dried *Termitomyces* spp packaged in rubber bag; blanched and sun dried *Termitomyces* spp packaged in plastic container; and sun dried oyster mushroom packaged in plastic container had the lowest but similar calcium values (0.001%). Baked and sun dried oyster mushroom packaged in plastic container had the highest amount of phosphorus (0.973mg/g) while blanched and sun dried oyster mushroom packaged in rubber bag had the lowest (0.221mg/g). Blanched and sun dried *Termitomyces* spp packaged in plastic container had the highest ash value (24.862%) while sun dried *Termitomyces* spp packaged in rubber bag had the lowest (7.555%). Sun dried *Termitomyces* spp packaged in rubber bag had the highest amount of energy (405.186 Kcal) while blanched and sun dried *Termitomyces* spp packaged in rubber bag had the lowest amount of energy (263.539 Kcal) (Table 4.6).

Table 4.6: Proximate composition of processed mushrooms stored at 4°C in rubber bags and plastic containers after 10 days (per 100 g sample)

| **Sample** | **Pack-aging** | **Treat-ment** | **Mois-ture** | **Protein** | **Carbo-hydrate** | **Fat** | **Ascorbic acid (mg/ml)** | **Zinc** | **Cal-cium** | **Phos-phorus (mg/g)** | **Ash** | **Energy (Kcal.)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Termito-myces | Rubber bag | Sun dried | 0.696 | 21.047 | 63.082 | **7.620** | 0.150 | 0.002 | 0.003 | 0.294 | **7.555** | **405.186** |
| | | Baked & dried | 2.549 | **7.873** | **80.761** | 0.513 | 0.123 | **0.001** | 0.002 | 0.928 | 8.304 | 359.153 |
| | | Blanched & dried | 4.459 | 15.913 | 57.573 | 0.195 | 0.090 | **0.001** | **0.001** | 0.415 | 21.860 | **263.539** |
| | | Mud oven dried | **2.825** | 16.391 | 71.446 | 1.266 | 0.221 | 0.002 | 0.002 | 0.414 | 8.072 | 362.742 |
| | Plastic container | Sun dried | 4.542 | 23.227 | 60.979 | 0.200 | 0.153 | 0.002 | 0.002 | 0.479 | 11.052 | 338.624 |
| | | Baked & dried | 4.034 | 21.338 | 61.967 | 3.194 | 0.120 | **0.001** | 0.002 | 0.285 | 9.467 | 361.966 |
| | | Blanched & dried | 1.068 | 18.735 | **54.453** | 0.882 | 0.082 | **0.001** | **0.001** | 0.561 | **24.862** | 300.690 |
| | | Mud oven dried | 1.945 | 22.516 | 66.399 | 0.210 | 0.232 | **0.003** | 0.002 | 0.704 | 8.930 | 357.550 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oyster mushroom | Rubber bag | Sun dried | 1.944 | 16.572 | 73.592 | 0.324 | 0.100 | 0.002 | 0.002 | 0.545 | 7.568 | 363.572 |
| | | Baked & dried | 1.150 | 16.680 | 72.211 | 1.269 | 0.120 | **0.003** | 0.002 | 0.733 | 8.690 | 366.985 |
| | | Blanched & dried | **0.599** | 14.612 | 65.181 | 1.081 | **0.060** | 0.002 | **0.006** | **0.221** | 18.527 | 328.901 |
| | | Mud oven dried | 1.703 | 16.887 | 70.630 | 1.249 | 0.423 | **0.003** | **0.006** | 0.377 | 9.531 | 361.309 |
| | Plastic container | Sun dried | 1.445 | 19.173 | 70.258 | 0.530 | 0.110 | 0.002 | **0.001** | 0.538 | 8.594 | 362.494 |
| | | Baked & dried | 1.060 | 17.783 | 73.237 | 0.214 | 0.122 | **0.003** | 0.002 | **0.973** | 7.706 | 366.006 |
| | | Blanched & dried | 1.435 | 10.671 | 68.936 | **0.100** | 0.062 | 0.002 | 0.002 | 0.257 | 18.858 | 319.328 |
| | | Mud oven dried | 1.010 | **23.526** | 65.328 | 0.417 | **0.430** | **0.003** | 0.002 | 0.518 | 9.719 | 359.169 |
| | | LSD(5%) | **0.0019** | **0.0020** | **0.0033** | **0.0020** | **0.0009** | **0.0004** | **0.0004** | **0.0018** | **0.0043** | **0.0042** |

*Values are expressed on dry weight basis*

Table 4.7 shows the results of processed mushrooms stored at 30 – 33$^{o}$C in rubber bags and plastic containers after 10 days. Different nutrient values were observed among the samples analyzed. Blanched and sun dried oyster mushroom packaged in plastic container had the highest moisture content (5.633%) while blanched and sun dried *Termitomyces* spp packaged in rubber bag had the lowest (0.755%). The protein value (23.234%) was significantly higher in mud oven dried oyster mushroom packaged in plastic container and lowest (10.432%) in baked and sun dried *Termitomyces* spp packaged in rubber bag. It was observed that baked and sun dried *Termitomyces* spp packaged in rubber bag had the highest carbohydrate value (78.442%) while blanched and sun dried *Termitomyces* spp packaged in plastic container had the lowest (50.492%). The fat content (7.232%) was significantly higher in sun dried *Termitomyces* spp packaged in rubber bag and lowest (0.112%) in blanched and sun dried oyster mushroom packaged in plastic container. The ascorbic acid values ranged from 0.065mg/ml for blanched and sun dried oyster mushroom packaged in plastic container to 0.549mg/ml for mud oven dried oyster mushroom packaged in rubber bag. Baked and sun dried *Termitomyces* spp packaged in rubber bag; blanched and sun dried *Termitomyces* spp packaged in rubber bag; and blanched and sun dried *Termitomyces* spp packaged in plastic container had the lowest zinc values (0.001%) while the rest were high in zinc values (0.003%). Mud oven dried *Termitomyces* spp packaged in rubber bag had significantly higher calcium content (0.007%) than the lowest value (0.001%) obtained for blanched and sun dried *Termitomyces* spp packaged in rubber bag; blanched and sun dried *Termitomyces* spp packaged in plastic container; sun dried oyster mushroom packaged in rubber bag; baked and sun dried oyster mushroom packaged in rubber bag;

and blanched and sun dried oyster mushroom packaged in plastic container. The result obtained showed that sun dried oyster mushroom packaged in rubber bag had the highest amount of phosphorus (0.821mg/g) while blanched and sun dried oyster mushroom packaged in plastic container had the lowest (0.204mg/g). There were different values obtained for the ash content in the processed mushrooms. Blanched and sun dried *Termitomyces* spp packaged in plastic container had significantly higher ash value (26.053%) compared to the lowest value (6.001%) obtained for sun dried oyster mushroom packaged in rubber bag. Sun dried *Termitomyces* spp packaged in rubber bag had the highest energy value (405.360 Kcal) while blanched and sun dried *Termitomyces* spp packaged in plastic container had the lowest (281.907 Kcal) (Table 4.7).

Table 4.7: Proximate composition of processed mushrooms stored at 30-33$^{o}$C in rubber bags and plastic containers after 10 days (per 100g sample)

| **Sample** | **Pack-aging** | **Treat-ment** | **Mois-ture** | **Protein** | **Carbo-hydrate** | **Fat** | **Ascorbic acid (mg/ml)** | **Zinc** | **Cal-cium** | **Phos-phorus (mg/g)** | **Ash** | **Energy (Kcal.)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Termi-tomyces | Rubber bag | Sun dried | 0.843 | 20.530 | 64.538 | **7.232** | 0.171 | 0.002 | 0.003 | 0.978 | 6.857 | **405.360** |
| | | Baked & sun | 3.441 | **10.432** | **78.442** | 0.502 | 0.115 | **0.001** | 0.002 | 0.225 | 7.183 | 360.014 |
| | | Blanched & dried | **0.755** | 15.351 | 63.462 | 0.160 | 0.092 | **0.001** | **0.001** | 0.461 | 20.272 | 316.692 |
| | | Mud oven dried | 3.354 | 16.200 | 72.139 | 1.254 | 0.240 | 0.002 | **0.007** | 0.494 | 7.053 | 364.642 |
| | Plastic container | Sun dried | 2.369 | 20.234 | 71.352 | 0.156 | 0.175 | 0.002 | 0.004 | 0.453 | 5.889 | 367.748 |
| | | Baked & dried | 5.038 | 20.891 | 64.467 | 3.011 | 0.120 | 0.002 | 0.002 | 0.710 | 6.593 | 368.531 |
| | | Blanched & dried | 4.449 | 18.223 | **50.492** | 0.783 | 0.090 | **0.001** | **0.001** | 0.436 | **26.053** | **281.907** |
| | | Mud oven dried | 3.265 | 21.544 | 67.460 | 0.201 | 0.235 | 0.002 | 0.002 | 0.740 | 7.530 | 357.825 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oyster mushroom | Rubber bag | Sun dried | 4.534 | 16.001 | 73.162 | 0.302 | 0.110 | **0.003** | **0.001** | **0.821** | **6.001** | 359.370 |
| | | Baked & dried | 3.814 | 16.561 | 71.187 | 1.245 | 0.128 | **0.003** | **0.001** | 0.302 | 7.193 | 362.197 |
| | | Blanched & dried | 5.277 | 14.576 | 61.317 | 1.054 | 0.068 | 0.002 | 0.002 | 0.373 | 17.776 | 313.058 |
| | | Mud oven dried | 4.478 | 16.445 | 69.077 | 1.121 | **0.549** | **0.003** | 0.003 | 0.369 | 8.879 | 352.177 |
| | Plastic container | Sun dried | 3.199 | 19.335 | 71.362 | 0.456 | 0.113 | **0.003** | 0.003 | 0.888 | 5.648 | 366.892 |
| | | Baked & dried | 0.955 | 18.543 | 73.332 | 0.210 | 0.124 | 0.002 | 0.003 | 0.617 | 6.960 | 369.390 |
| | | Blanched & dried | **5.633** | 11.012 | 65.189 | **0.112** | **0.065** | 0.002 | **0.001** | **0.204** | 18.054 | 305.812 |
| | | Mud oven dried | 5.315 | **23.234** | 62.890 | 0.402 | 0.544 | 0.002 | 0.003 | 0.230 | 8.159 | 348.114 |
| | | LSD (5%) | **0.0079** | **0.0699** | **0.0582** | **0.0070** | **0.0076** | **0.0006** | **0.0003** | **0.0070** | **0.0081** | **2.4460** |

*Values are expressed on dry weight basis*

The analysis was repeated after 20 days of storage and the results are shown in tables 4.8 and 4.9.

There were significant differences ($p < 0.05$) among all the treatments of the mushrooms which were stored at 4$^{o}$C in rubber bags and plastic containers after 20 days. It was observed that sun dried *Termitomyces* spp packaged in plastic container had the highest moisture value (4.678%) while sun dried *Termitomyces* spp packaged in rubber bag had the lowest (0.540%). For mud oven dried oyster mushroom packaged in plastic container, protein value (23.522%) was significantly higher than the lowest value (10.133%) obtained for baked and sun dried *Termitomyces* spp packaged in rubber bag. The carbohydrate (77.934%) value was highest in baked and sun dried *Termitomyces* spp packaged in rubber bag and lowest (53.891%) in blanched and sun dried *Termitomyces* spp packaged in plastic container. The fat content (7.606%) was highest in sun dried *Termitomyces* spp packaged in rubber bag as compared to the lowest value (0.154%) obtained for sun dried *Termitomyces* spp packaged in plastic container. It was observed that mud oven dried oyster mushroom packaged in plastic container had the highest amount of ascorbic acid (0.550mg/ml) while blanched and sun dried oyster mushroom packaged in plastic container had the lowest (0.064mg/ml). Baked and sun dried *Termitomyces* spp packaged in rubber bag; baked and sun dried *Termitomyces* spp packaged in plastic container; and blanched and sun dried *Termitomyces* spp packaged in plastic container had the lowest zinc values (0.001%) while the rest were high in zinc values (0.003%). The calcium value (0.007%) was significantly higher in mud oven dried oyster mushroom packaged in rubber bag while the rest were low in calcium values (0.001%). Baked and sun dried oyster mushroom packaged in plastic container had the highest phosphorus value (0.978mg/g) while the lowest value (0.231mg/g) was observed in blanched and sun dried oyster mushroom packaged in rubber bag. The ash values varied from the samples analyzed. Blanched and sun dried *Termitomyces* spp packaged in plastic container recorded the highest ash value (25.387%) while baked and sun dried oyster mushroom packaged in plastic container had the lowest (8.021%). The energy value (402.302 Kcal) was observed to be highest in sun dried *Termitomyces* spp packaged in rubber bag and lowest (294.756 Kcal) in blanched and sun dried *Termitomyces* spp packaged in rubber bag (Table 4.8).

Table 4.8: Proximate composition of processed mushrooms stored at 4°C in rubber bags and plastic containers after 20 days (per 100 g sample)

| Sample | Packaging | Treatment | Moisture | Protein | Carbohydrate | Fat | Ascorbic acid (mg/ml) | Zinc | Calcium | Phosphorus (mg/g) | Ash | Energy (Kcal.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Termitomyces | Rubber bag | Sun dried | **0.540** | 21.112 | 62.350 | **7.606** | 0.172 | 0.002 | 0.003 | 0.298 | 8.392 | **402.302** |
| | | Baked & dried | 2.392 | **10.133** | **77.934** | 0.520 | 0.127 | **0.001** | 0.002 | 0.943 | 9.021 | 356.948 |
| | | Blanched & dried | 4.545 | 15.811 | 57.455 | 0.188 | 0.086 | 0.002 | **0.001** | 0.432 | 22.001 | **294.756** |
| | | Mud oven dried | 2.734 | 17.102 | 68.738 | 1.324 | 0.320 | **0.003** | 0.003 | 0.441 | 10.102 | 355.276 |
| | Plastic container | Sun dried | **4.678** | 23.201 | 60.466 | **0.154** | 0.175 | 0.002 | 0.002 | 0.488 | 11.501 | 336.054 |
| | | Baked & dried | 4.100 | 21.410 | 61.083 | 3.182 | 0.128 | **0.001** | 0.002 | 0.287 | 10.225 | 358.610 |
| | | Blanched & dried | 1.002 | 18.862 | **53.891** | 0.858 | 0.085 | **0.001** | **0.001** | 0.570 | **25.387** | 298.734 |
| | | Mud oven dried | 1.924 | 23.101 | 64.792 | 0.201 | 0.300 | **0.003** | 0.002 | 0.732 | 9.982 | 353.381 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oyster mushroom | Rubber bag | Sun dried | 2.005 | 16.675 | 70.048 | 0.385 | 0.122 | **0.003** | 0.002 | 0.554 | 10.887 | 350.357 |
| | | Baked & dried | 1.011 | 16.708 | 72.419 | 1.639 | 0.130 | **0.003** | 0.002 | 0.735 | 8.223 | 371.259 |
| | | Blanched & dried | 0.601 | 14.504 | 64.535 | 1.326 | 0.065 | 0.002 | 0.006 | **0.231** | 19.034 | 328.090 |
| | | Mud oven dried | 1.733 | 16.913 | 69.587 | 1.530 | 0.548 | **0.003** | **0.007** | 0.386 | 10.237 | 359.770 |
| | Plastic container | Sun dried | 1.454 | 19.210 | 68.001 | 0.561 | 0.124 | 0.002 | **0.001** | 0.547 | 10.774 | 353.893 |
| | | Baked & dried | 1.055 | 17.507 | 73.114 | 0.303 | 0.129 | **0.003** | 0.002 | **0.978** | **8.021** | 365.211 |
| | | Blanched & dried | 1.470 | 10.611 | 68.687 | 0.231 | **0.064** | 0.002 | 0.002 | 0.265 | 19.001 | 319.271 |
| | | Mud oven dried | 1.023 | **23.522** | 64.924 | 0.508 | **0.550** | **0.003** | 0.002 | 0.521 | 10.023 | 358.356 |
| | | LSD (5%) | **0.0527** | **0.0627** | **0.0079** | **0.0055** | **0.0077** | **0.0012** | **0.0015** | **0.0070** | **0.0056** | **0.0299** |

*Values are expressed on dry weight basis*

Table 4.9 shows the results of processed mushrooms stored at 30-33$^{o}$C in rubber bags and plastic containers after 20 days. There were significant differences ($p < 0.05$) among all the treatments stored. It was observed that baked and sun dried *Termitomyces* spp packaged in plastic container had the highest moisture value (6.101%) while blanched and sun dried *Termitomyces* spp packaged in rubber bag had the lowest (0.761%). The protein value (23.449%) was found to be highest in mud oven dried oyster mushroom packaged in plastic container while baked and sun dried *Termitomyces* spp packaged in rubber bag had the lowest (9.987%). The analysis revealed different carbohydrate values of the stored samples. Baked and sun dried *Termitomyces* spp packaged in rubber bag had the highest carbohydrate value (75.964%) while blanched and sun dried *Termitomyces* spp packaged in plastic container had the lowest (50.655%). The fat values ranged from 0.120% to 8.111%. Sun dried *Termitomyces* spp packaged in rubber bag had the highest while blanched and sun dried oyster mushroom packaged in plastic container had the lowest. The ascorbic acid value (0.560mg/ml) was found to be highest in mud oven dried oyster mushroom packaged in rubber bag while blanched and sun dried oyster mushroom packaged in plastic container had the lowest (0.068mg/ml). Sun dried *Termitomyces* spp packaged in plastic container; mud oven dried *Termitomyces* spp packaged in plastic container; sun dried oyster mushroom packaged in rubber bag; baked and sun dried oyster mushroom packaged in rubber bag; mud oven dried oyster mushroom packaged in rubber bag; and sun dried oyster mushroom packaged in plastic container had the highest but similar amount of zinc (0.003%). Conversely, baked and sun dried *Termitomyces* spp packaged in rubber bag; blanched and sun dried *Termitomyces* spp packaged in rubber bag; and blanched and sun dried *Termitomyces* spp packaged in plastic container had the lowest but similar zinc values (0.001%). Different trends were observed for calcium values in the stored samples. Mud oven dried *Termitomyces* spp packaged in rubber bag had the highest calcium value (0.007%) while blanched and sun dried *Termitomyces* spp packaged in rubber bag; blanched and sun dried *Termitomyces* spp packaged in plastic container; baked and sun dried oyster mushroom packaged in rubber bag; and blanched and sun dried oyster mushroom packaged in plastic container had the lowest but similar calcium values (0.001%). The phosphorus value (0.988mg/g) was highest in sun dried *Termitomyces* spp packaged in rubber bag while blanched and sun dried oyster mushroom packaged in plastic container had the lowest (0.223mg/g). It was observed that blanched and sun dried *Termitomyces* spp packaged in plastic container had the highest ash value (25.031%) while baked and sun dried oyster mushroom packaged in plastic container had the lowest (7.879%). The energy value (402.659 Kcal) was found to be highest in sun dried *Termitomyces* spp packaged in rubber bag while blanched and sun dried *Termitomyces* spp packaged in plastic container had the lowest (286.258 Kcal) (Table 4.9).

Table 4.9: Proximate composition of processed mushrooms stored at 30-33$^oC$ in rubber bags and plastic containers after 20 days (per 100 g sample)

| Sample | Packaging | Treatment | Moisture | Protein | Carbohydrate | Fat | Ascorbic acid (mg/ml) | Zinc | Calcium | Phosphorus (mg/g) | Ash | Energy (Kcal.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Termitomyces | Rubber bag | Sun dried | 0.840 | 20.978 | 61.437 | **8.111** | 0.165 | 0.002 | 0.003 | **0.988** | 8.634 | **402.659** |
| | | Baked & dried | 3.501 | **9.987** | **75.964** | 0.560 | 0.123 | **0.001** | 0.002 | 0.235 | 9.988 | 348.844 |
| | | Blanched & dried | **0.761** | 16.102 | 60.856 | 0.199 | 0.094 | **0.001** | **0.001** | 0.476 | 22.082 | 309.623 |
| | | Mud oven dried | 3.631 | 16.221 | 69.025 | 1.332 | 0.260 | 0.002 | **0.007** | 0.497 | 9.791 | 352.972 |
| | Plastic container | Sun dried | 2.453 | 23.001 | 62.342 | 0.201 | 0.169 | **0.003** | 0.004 | 0.467 | 12.003 | 343.181 |
| | | Baked & dried | **6.101** | 21.079 | 59.620 | 3.189 | 0.122 | 0.002 | 0.002 | 0.721 | 10.011 | 351.497 |
| | | Blanched & dried | 4.652 | 18.664 | **50.655** | 0.998 | 0.098 | **0.001** | **0.001** | 0.445 | **25.031** | **286.258** |
| | | Mud oven dried | 3.450 | 22.603 | 64.639 | 0.303 | 0.262 | **0.003** | 0.003 | 0.756 | 9.005 | 351.695 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oyster mushroom | Rubber bag | Sun dried | 5.022 | 16.557 | 69.671 | 0.430 | 0.153 | **0.003** | 0.002 | 0.843 | 8.320 | 348.782 |
| | | Baked & dried | 3.821 | 16.655 | 68.584 | 1.937 | 0.140 | **0.003** | **0.001** | 0.311 | 9.003 | 358.389 |
| | | Blanched & dried | 5.242 | 14.501 | 56.908 | 1.139 | 0.070 | 0.002 | 0.002 | 0.377 | 19.210 | 295.887 |
| | | Mud oven dried | 4.403 | 16.703 | 67.641 | 1.252 | **0.560** | **0.003** | 0.003 | 0.377 | 10.001 | 348.644 |
| | Plastic container | Sun dried | 3.190 | 19.202 | 67.906 | 0.651 | 0.150 | **0.003** | 0.003 | 0.898 | 9.051 | 354.291 |
| | | Baked & dried | 0.961 | 17.720 | 73.213 | 0.227 | 0.138 | 0.002 | 0.003 | 0.623 | **7.879** | 365.775 |
| | | Blanched & dried | 5.703 | 10.551 | 64.601 | **0.120** | **0.068** | 0.002 | **0.001** | **0.223** | 19.025 | 301.688 |
| | | Mud oven dried | 5.302 | **23.449** | 60.389 | 0.539 | 0.520 | 0.002 | 0.003 | 0.234 | 10.321 | 340.203 |
| | | LSD (5%) | **0.0053** | **0.0155** | **0.0075** | **0.0031** | **0.0024** | **0.0004** | **0.0005** | **0.0012** | **0.0019** | **0.0021** |

*Values are expressed on dry weight basis*

Tables 4.10 and 4.11 show the results of the sensory evaluation conducted by 50 untrained panelists on the acceptability of four processed mushroom samples from two varieties of mushrooms in the Kpelezo community. The panelists preferred sun dried oyster mushroom appearance and scored it highest in appearance, texture, size, aroma while blanched and sun dried oyster mushroom was scored lowest in appearance, size and aroma. The panelists preferred the taste of blanched and sun dried oyster mushroom and scored it highest but disliked the texture of mud oven dried, and the taste and aroma of baked and sun dried oyster mushroom and scored them lowest (Table 4.10).

Table 4.10: Consumer evaluation of dried Oyster Mushroom

| Sample | Attribute | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Appearance** | | **Texture** | | **Size** | | **Taste** | | **Aroma** | |
| | Score | NoR | Score | NoR | Score | NoR | Score | NoR | Score | NoR |
| Sun dried | 30 | 30 | 15 | 35 | 20 | 27 | 25 | 20 | 10 | 40 |
| | 20 | 15 | 10 | 12 | 12 | 13 | 16 | 20 | 6 | 8 |
| | 10 | 5 | 5 | 3 | 6 | 10 | 8 | 10 | 3 | 2 |
| Baked & dried | 30 | 20 | 15 | 17 | 20 | 14 | 25 | 21 | 10 | 14 |
| | 20 | 13 | 10 | 15 | 12 | 18 | 16 | 11 | 6 | 16 |
| | 10 | 17 | 5 | 18 | 6 | 18 | 8 | 18 | 3 | 20 |
| Blanched & dried | 30 | 13 | 15 | 16 | 20 | 18 | 25 | 35 | 10 | 12 |
| | 20 | 16 | 10 | 14 | 12 | 2 | 16 | 10 | 6 | 18 |
| | 10 | 21 | 5 | 20 | 6 | 30 | 8 | 5 | 3 | 20 |
| Mud oven dried | 30 | 23 | 15 | 14 | 20 | 18 | 25 | 22 | 10 | 21 |
| | 20 | 11 | 10 | 15 | 12 | 12 | 16 | 13 | 6 | 12 |
| | 10 | 16 | 5 | 21 | 6 | 20 | 8 | 15 | 3 | 17 |

NoR = Number of Respondent

From Table 4.11, the panelists preferred the mud oven dried *Termitomyces* spp and scored it highest in appearance, texture, size, taste and aroma while blanched and sun dried *Termitomyces* spp was scored lowest in appearance, texture and size. The panelists disliked the taste and aroma of baked and sun dried *Termitomyces* spp and scored it the lowest (Table 4.11).

Table 4.11: Consumer evaluation of dried Wild Mushroom

| Sample | Attribute | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Appearance** | | **Texture** | | **Size** | | **Taste** | | **Aroma** | |
| | Score | NoR | Score | NoR | Score | NoR | Score | NoR | Score | NoR |
| | 30 | 14 | 15 | 20 | 20 | 18 | 25 | 21 | 10 | 20 |
| Sun dried | 20 | 20 | 10 | 18 | 12 | 15 | 16 | 15 | 6 | 13 |
| | 10 | 16 | 5 | 12 | 6 | 17 | 8 | 16 | 3 | 17 |
| | 30 | 19 | 15 | 17 | 20 | 22 | 25 | 15 | 10 | 19 |
| Baked & dried | 20 | 20 | 10 | 13 | 12 | 14 | 16 | 17 | 6 | 11 |
| | 10 | 11 | 5 | 20 | 6 | 14 | 8 | 18 | 3 | 20 |
| | 30 | 11 | 15 | 13 | 20 | 12 | 25 | 23 | 10 | 13 |
| Blanched & dried | 20 | 14 | 10 | 15 | 12 | 17 | 16 | 12 | 6 | 18 |
| | 10 | 25 | 5 | 22 | 6 | 21 | 8 | 15 | 3 | 19 |
| | 30 | 33 | 15 | 28 | 20 | 29 | 25 | 25 | 10 | 23 |
| Mud oven dried | 20 | 14 | 10 | 12 | 12 | 13 | 16 | 10 | 6 | 11 |
| | 10 | 3 | 5 | 10 | 6 | 9 | 8 | 15 | 3 | 16 |

NoR = Number of Respondent

# CHAPTER FIVE

## 5.0 DISCUSSION

Kpelezo is predominantly a farming community in the Volta Region of Ghana. The majority of the farmers are male with female forming the minority. This statistics translated in more males engaging in wild mushrooms harvesting than females. Generally in Ghanaian traditional settings, women engage more in household chores than men.

The majority of farmers harvested mushrooms when the veils are not opened. They claimed, mushrooms harvested this way are more prized and less susceptible to diseases and pests attack. Santosh *et al*. (2014) and Oei (2003) stated that mushroom harvested with veil yet to open are more expensive than those with opened veil. Wild mushrooms collectors are ignorant that continuous exposure of harvested mushrooms to air could lead to contamination, pests and diseases attack which will eventually result in the deterioration of the product. Oei (2003) proposed that fresh mushroom should be handled with minimal touch and exposure otherwise lead to postharvest contamination of the product. Mushrooms are harvested early morning to enable sales to customers. Harvesting of the mushroom was done by holding the stalk and gently pulling it which enabled all the parts of the mushrooms to be harvested intact and prevent bruise. Oei (2003) reported that mushrooms should be harvested by gently pulling them from the soil as bruised mushroom hastened spoilage. However, in compacted soil, farmers dug soil around the mushrooms before pulling them to prevent cap and stalk from breaking. Mushrooms harvested with broken stalk and cap are less prized and susceptible to microbial attack (Santosh *et al*., 2014).

Most farmers believed that pretreating fresh mushrooms with water before sale could increase their rate of deterioration. They explained that the mushrooms absorb and if they are not sold early they deteriorate. Fresh mushrooms harvested by farmers were not packaged in any form before they were sold to consumers. Rather the mushrooms were tied with threads and displayed at the roadside. This practice resulted in multiple handling of the mushroom by sellers and buyers. Oei (2003) proposed that mushrooms should be harvested with minimum touch and handling otherwise they are easily contaminated. Mushrooms that are not sold were processed by farmers in different ways. Baking and sun drying are the most common processing techniques used by farmers. But the appearance of some of the farmers' samples showed that proper procedures for baking and sun drying were not followed. The higher postharvest loss values of fresh mushrooms observed could be as a result of improper and untimely harvesting as well as mishandling, pest and disease attack of the mushrooms (Santosh *et al*., 2014).

The appearances of the processed samples showed changes in colour. This can be due to the different temperature treatments and the pretreatments of the mushroom samples. The blanched samples at salt concentration of 20g per 500ml of water for 15 minutes before drying showed a different colour as compared to the rest of the processed samples. For *Termitomyces* spp, the initial white colour changed to cream colour while the *Pleurotus ostreatus* changed from white to brown. The sodium chloride (salt) solution might have slowed down the enzymatic reaction in the *Termitomyces* spp. Rai and Arumuganathan (2008) and Byung (2004) asserted that blanching mushrooms in brine solution inhibit enzymes activity and inactivate microorganisms. Some mushroom samples baked before drying and mud oven drying were brown and may be due to maillard reactions (Oei, 2003). Samples subjected to mud oven drying at a temperature of 80$^{o}$C for 2 hours showed creamy to brown colour than shown by the rest of the processed samples which may be attributed to enzymatic and non-enzymatic browning reactions (Byung, 2004). The exposure of mushrooms to direct heat before drying under the sun reduced the moisture content in the mushroom considerably. Reduction in moisture content of the mushroom prevents early deterioration of the product (Oei, 2003; Rai and Arumuganathan, 2008).

The protein content of the fresh mushrooms was found to be 0.858% and 2.095% in *Pleurotus ostreatus* and *Termitomyces* spp respectively (Table 4.4). The protein content of *Pleurotus ostreatus* (0.858%) was considerably lower than 27.25% obtained by other authors (Rai and Arumuganathan, 2008). The protein content obtained for *Termitomyces* spp was also much lower than the value of 34.36% reported by Crabbe (2010). Some of the factors that influence protein content in mushroom are the composition of the substrate, size of the pileus, harvesting time and the mushroom species (Bernaś *et al*., 2006). This could explain the low level of protein in the fresh mushrooms analyzed. Again, the values obtained varied because the samples were not grown under similar conditions. The methods for protein analysis used by the authors may vary as well. The methods of packaging and the types of packaging material used could influence the nutritional composition of the product. Mateljan (2014) opined that mushroom package with caps touching each other and stored at a temperature of 4$^{o}$C or below contribute to nutritional losses of the product. For the two species, the carbohydrate contents for the samples were 7.358% and 8.303% (Table 4.4). The value of carbohydrate content in *Pleurotus ostreatus* was quite lower than value 35.31% recorded by Rai and

Arumuganathan (2008). The fat content for *Pleurotus ostreatus* was 6.333% and that of *Termitomyces* spp was 8.124% (Table 4.4). These values were considerably higher than 2.75% recorded by Rai and Arumuganathan (2008) and 1.40% by Crabbe (2010). Carbohydrate and fat values differed because the mushrooms were not grown under similar conditions. The processing method employed also differed from one sample to the other. Mshandete and Cuff (2007) opined that the fat content of mushroom varies depending upon the cooking method employed. It could be argued that since the mushroom was not subjected to much heat the fat content was comparably higher than what has been reported by Rai and Arumuganathan (2008) and Crabbe (2010). Mushrooms are rich in potassium, phosphorus, zinc, copper and cadmium (Arés *et al*., 2007). Zinc, calcium and phosphorus were some of the nutrients in *Pleurotus ostreatus* and *Termitomyces* spp studied. The zinc content of *Termitomyces* spp and *Pleurotus ostreatus* were 0.038% and 0.037% respectively. These values were comparatively lower than 4.92mg/g and 12.9mg/g reported by Devi *et al*. (2014) and Ahmed *et al*. (2013), respectively. The phosphorus values of *Termitomyces* spp and *Pleurotus ostreatus* were 0.460% and 0.346%. These values were lower than 239.4mg/g and 8.0mg/g reported by Obodai and Apertorgbor (2009) and Ahmed *et al*. (2013), respectively. Differences in values obtained could be attributed to the strain types and the stages of development of the mushrooms. Devi *et al*. (2014) reported that mineral concentration in mushrooms can be influenced by the strain type, stage of the mushroom, the composition of the growth substrate and the environment. The ascorbic acid was present in lower amount of 0.015mg/ml in both species. The ash content of 0.603% in *Termitomyces* spp and 0.584% in *Pleurotus ostreatus* was comparatively lower than 6.12% reported by Crabbe (2010).

This might be due to differences in processing methods employed (Bernaś *et al*., 2006). The energy value obtained for *Termitomyces* spp was 114.712 Kcal and that of *Pleurotus ostreatus* was 89.861 Kcal. The energy value of 89.861 Kcal obtained was comparatively higher than 28 Kcal of *P. ostreatus* obtained by Mattila *et al*. (2002). This might be due to the level of fat and carbohydrate contents in the mushrooms, which are concentrated source of energy (Dunkwal *et al*., 2007).

Soon after processing, the eight samples were subjected to proximate composition analysis to ascertain the effect of the techniques on the nutritional composition of the mushrooms. The proximate analysis revealed contrasting values as compared to the fresh samples analyzed the same way.

The final moisture content of *Termitomyces* spp ranged from 11.942% to 16.034% while *Pleurotus ostreatus* values ranged from 10.566% to 14.401%. Sun dried *Termitomyces* spp recorded the highest value of 16.034% and *Pleurotus ostreatus* baked and sun dried recorded the lowest value of 10.566% (Table 4.5). The lower moisture content of 10.566% recorded by *Pleurotus ostreatus* baked before drying could be explained as a result of a rapid dehydration of the mushroom due to preheat treatment (baking) employed. Even though the process of sun drying of this sample lasted for 5 days in contrast with the 7 days sun drying; and blanching and sun drying for other samples, the pretreatment probably might have caused heat damage and collapse of the internal cells of mushroom thus allowing rapid evaporation of water from the mushroom surface. The highest moisture content of 16.034% recorded by sun dried *Termitomyces* spp could be attributed to the limited period of drying the mushrooms.

Protein, one of the major nutrients in the mushroom, was found to range from 1.733% to 20.804% among the samples processed. Mud oven dried *Termitomyces* spp recorded the highest value of 20.804% and blanched and sun dried *Pleurotus ostreatus* the lowest value of 1.733% (Table 4.5). The protein range of 5.567% to 20.804% of the processed *Terrmitomyces* spp was comparable within the value of 19.6% obtained by Obodai and Apertorgbor (2009). Contrary, the range of 1.733% to 19.839% of the processed *Pleurotus ostreatus* was below the value of 25.0% obtained by Oei (2003). The *Pleurotus ostreatus* blanched in boiled water containing 20 g of NaCl for 15 minutes before drying recorded lower value of protein as compared to sun dried sample. The low protein value might be due to increase protein denaturation. Galoburda *et al*. (2015) opined that at higher blanching temperature of 100$^{o}$C, the protein content in the mushrooms denatured as well as the soluble components in the mushrooms into the blanching medium. Bernaś *et al*. (2006) stated that blanching mushrooms for 15 minutes in salt solution decreases the dry matter content by 20%; total sugar by 5%; and protein content by 12%. Since the value of 20.804% protein content of mud oven dried *Termitomyces* spp was within the value reported by other authors (Oei, 2003), it could be argued that mud oven drying provides the best way of maintaining protein content in this mushroom followed by sun drying. However, baking and blanching in salt solution before drying are not the best methods of mushroom processing as these methods reduce the nutrient content in the mushroom. Contrary, sun drying of *Pleurotus ostreatus* maintains protein content better in the mushroom followed by mud oven drying. However in sun drying, care must be taken to prevent contamination of the product (Oei, 2003). In view of the results obtained for the protein levels of *Termitomyces* spp and *Pleurotus ostreatus* in this study, it is suggested that processing of these mushrooms in the future be encouraged in areas where they are harvested in abundance.

Carbohydrate content in the mushrooms varied depending on the type of processing technique used for each group. In the sample of the processed *Termitomyces* spp, the carbohydrate content ranged from 57.890% to 73.022% (Table 4.5). These values were above the value of 36.7% recorded by Obodai and Apertorgbor (2009). Lower ranges of 57.480% to 68.729% were observed in *P. ostreatus* as compared to the range observed in the *Termitomyces* spp. The average value of 62.208% was above the value recorded by Obodai and Apertorgbor (2009). From the values obtained for carbohydrate, it could be argued that the processing maintained the carbohydrate content of the mushrooms as the values obtained were comparatively higher than the values indicated by some authors.

The fat content varied from processed mushrooms. *P. ostreatus* baked and sun dried contained the highest value of 12.646% and the lowest value of 0.045% was found in *P. ostreatus* baked and sun dried. These values are comparable with the values of 1.1% to 2.0% obtained by Obodai and Apertorgbor (2009). This was because the substrate on which the mushroom was cultivated was rich in nutrients. The higher the substrate nutrient the higher the nutrient composition of the mushroom (Mshandete and Cuff, 2007). The *P. ostreatus* blanched and sun dried had the highest ash content of 15.092% followed by *Termitomyces* spp blanched and sun dried. The higher ash content of 15.092% could be attributed to the dipping of the mushroom in salt solution. Bernaś *et al*. (2006) reported that blanching mushroom in salt solution increase sodium, calcium and iron level. According to Kaul (2001), about 70% of minerals in mushrooms are phosphorus, potassium and sodium. Blanching the mushroom in salt solution would increase the potassium, sodium and calcium level thereby increasing the ash value.

The mineral content of zinc, calcium and phosphorus determined in the mushrooms are in minimal amount. *Pleurotus ostreatus* that was mud oven dried contained the highest value of 0.054% for zinc (Table 4.5). *Termitomyces* spp mud oven dried contained the highest value of 0.806% for phosphorus. The energy value ranged from 282.253 Kcal obtained for *P. ostreatus* blanched and sun dried to 402.646 Kcal for the same species baked and sun dried. It could be said from the results obtained that the energy value of blanched and sun dried samples were lower than the rest of the processed samples. It could be argued that blanching of the mushroom in salt solution causes leaching of some of the nutrients into solution thereby influencing the value obtained. This is because in determining the energy value, the values of fat, protein and carbohydrate are used. During blanching, these nutrients leached into the blanching medium (Bernaś *et al*., 2006; Galoburda *et al*., 2015) and contributed to the overall decline in the energy value of the blanched product.

The results from Tables 4.6 and 4.7 indicated a drastic reduction in moisture content in each sample. Prior to packaging and storage, the moisture content of the samples ranged from 10.566% to 16.034% with sun dried *Termitomyces* spp recording the highest moisture content of 16.034% while baked and sun dried *P. ostreatus* recorded the lowest. After packaging and storage during the 10 days period, the moisture content of samples stored in the refrigerator at $4^{o}$C ranged from 0.599% to 4.542% and that at room storage at 30 – $33^{o}$C ranged from 0.755% to 5.633%. Comparing the results of Tables 4.6 and 4.7

with Table 4.5, it could be noted that there was exchange of moisture of the products with the environment. These changes in moisture content of the products could be attributed to low relative humidity (65-70%) experienced during the storage period. The values of moisture content obtained for the products stored at 30 – 33$^{o}$C were higher than those stored at 4$^{o}$C (Table 4.6 and 4.7). From the two ranges (0.599% to 4.542% and 0.755% to 5.633%), it could be argued that storing the processed mushrooms at 4$^{o}$C preserve it better than storing it at 30 – 33$^{o}$C. For the higher the moisture contents of the product the greater the susceptibility of the product to microbial attack (Rai and Arumuganathan, 2008).

The values of protein content for the stored product in the two storage environments are different in relation to the type of processing techniques used. The lowest protein values were recorded for baked and sun dried *Termitomyces* spp while *P. ostreatus* that is mud oven dried recorded the highest protein value of 23.526%. For *Termitomyces* spp, the protein content varied from 7.873% to 23.227%. These values are comparable with the value of 19.6% obtained by Obodai and Apertorgbor (2009). Besides, the value obtained for protein in the processed *P. ostreatus* varied from 10.671% to 23.526%. These values are however lower than the value of 27.0% obtained by Oei (2003). In comparing the results of Table 4.6 with Table 4.7, it was evidently clear that no substantial reduction in protein content of the processed mushroom was recorded during the storage period. It could also be argued that the packaging and storage of the processed mushrooms for the 10 days period has no significant effect on the protein content.

The carbohydrate content for both products stored in the two different environments showed contrasting values. The values of carbohydrate content for stored product at $4^oC$ ranged from 54.453% to 80.761% and the average value was 67.252%. Contrary to samples stored at 30 – $33^oC$, the carbohydrate content ranged from 50.492% to 78.442% and the average was recorded as 67.492%. In comparing the values of the two storage conditions, it could be argued that samples stored in refrigerator preserve the carbohydrate content better than those stored at room temperature although the differences in value for the two storage conditions are not significant. In calculating the carbohydrate value, the values of protein, fat and ash are used. The rate of oxidative rancidity and microbial activity are reduced when samples are kept in refrigerator (Dilbaghi and Sharma, 2007). This might have influenced the values obtained.

There was a reduction in values of fat during the 10 days storage period in both storage conditions in comparison with the fat values obtained prior to packaging and storage (Table 4.5). The fat content varied from 0.100% to 7.620% (Table 4.6) during the 10 days period for refrigerator storage while the room storage values varied from 0.112% to 7.232% (Table 4.7). All the samples recorded reduction in fat values after storage except sun dried *Termitomyces* spp packaged in rubber bag and plastic container (Tables 4.6 and 4.7). The range of values from 0.210% to 7.620% obtained for *Termitomyces* spp stored at $4^oC$ are comparable with the value of 2.9% obtained by Obodai and Apertorgbor (2009) and 1.40% obtained by Crabbe (2010). In contrast, the range of 0.100% to 1.269% obtained for *P. ostreatus* stored at $4^oC$ was below the value of 1.6% obtained by Oei (2003) and 1.32% obtained by Rai and Arumuganathan (2008). The low fat levels recorded among samples could be attributed to reaction between fat and reducing sugars among the stored samples (Ahmed *et al*., 2014). Also, differences between values obtained by other authors was as a result of differences in geographical locations in which the mushrooms are grown as well as the substrate composition from which the mushrooms were harvested (Mshandete and Cuff, 2007).

Zinc, calcium and phosphorus were the mineral elements studied in the processed mushrooms. No significant changes in values were seen in zinc, calcium and phosphorus content in the processed mushrooms during the 10 days storage period for the two storage conditions. The temperature of the storage environment, the prevailing relative humidity during the storage period and the packaging materials had little influence on the mineral composition of the processed mushrooms.

The percentage ash content in the processed mushrooms increased considerably during the 10 days period as compared to the ash values recorded prior to storage of the samples (Table 4.5). The values of the ash content varied from 7.555% to 24.862% (Table 4.6) for samples stored in refrigerator and 5.648% to 26.053% (Table 4.7) for samples stored at room temperature. The values of the ash content for processed *Termitomyces* spp varied from 7.555% to 24.862% while *P. ostreatus* ash values range from 7.568% to 18.858% for the same storage condition (Table 4.6). For room storage condition, the values of ash content in the processed mushroom varied from 5.889% to 26.053% for *Termitomyces* spp while *P. ostreatus* recorded a range in ash values of 5.648% to 18.054%. These values are higher than the values obtained by Obodai and Apertorgbor (2009). From all the values obtained, blanched and sun dried samples recorded the highest ash value after the 10 days storage period. The scientific reasons why the blanched samples recorded the highest ash content could not be established by the researcher but it could be argued that the salt content might have contributed to these values.

The energy values for both storage conditions recorded different but closer values. The energy values were found to range from 263.539 Kcal to 405.186 Kcal for product stored at 4$^{o}$C while a range of 281.907 Kcal to 405.360 Kcal were recorded for samples stored at 30 – 33$^{o}$C. *Termitomyces* spp sun dried recorded the highest energy value in both storage conditions while the lowest energy values of 263.539 Kcal and 281.907 Kcal were recorded for *Termitomyces* spp blanched and sun dried and stored at 4$^{o}$C and 30 – 33$^{o}$C, respectively. These energy values are comparable with the values of 229.800 Kcal for *Termitomyces* spp and 279.900 Kcal for *P. ostreatus* obtained by Obodai and Apertorgbor (2009). It can be stated that the packaging and the storage temperature has no effect on the energy values of the product.

The moisture content of the mushrooms in Tables 4.8 and 4.9 were found to vary from 0.540% to 4.678% in samples stored at 4$^{o}$C and 0.761% to 6.101% for samples stored at 30 – 33$^{o}$C. These moisture content changes insignificantly in value as compared to samples analyzed after 10 days storage period. It could be argued that relative humidity in the storage environment was favourable hence not much exchange of moisture occurred between the products and the environment. However, there was little gain in moisture value of most of the product in Table 4.8 over the 20 days storage period. It could be concluded that the packaging and storage condition help maintain moisture content over the storage period.

The value of protein content of the mushrooms after 20 days showed little change in value as compared to the 10 days storage period. The value was found to range from 10.133% to 23.522% among the mushroom species processed and stored at 4$^{o}$C while a range of 9.987% to 23.449% was recorded among species processed and stored at 30 – 33$^{o}$C over the 20 days storage period. The average protein content of the processed mushroom was 17.899% for refrigerator storage and 17.748% for samples stored in room. *P. ostreatus* mud oven dried recorded the highest protein value of 23.522% and *Termitomyces* spp baked and dried the lowest value of 10,133% (Table 4.8) for sample analyzed after 20 days of storage at 4$^{o}$C. For sample stored at 30 – 33$^{o}$C, mud oven drying recorded the highest value of 23.449% while *Termitomyces* spp baked and sun dried recorded the lowest value of 9.987% (Table 4.9). The protein content of the processed *Termitomyces* spp ranged from 10.133% to 23.101% and this was comparable with 19.6% obtained by Obodai and Apertorgbor (2009). The protein content determined for *P. ostreatus* stored at 4$^{o}$C ranged from 10.611% to 23.522% and this value was lower than 25.0% obtained by Oei (2003). From Table 4.9, the protein content for *Termitomyces* spp varied from 9.987% to 23.001% for product stored at 30 – 33$^{o}$C for 20 days while *P. ostreatus* recorded a range of 10.551% to 23.449% for the same period. The values indicated insignificant change in protein content in terms of the treatment applied to the various groups. It can therefore be argued that the packaging and the storage environment had no significant effect on the result of the protein value obtained in comparison with the results recorded after the 10 days storage period.

The carbohydrate content for the 20 days period at 4$^{o}$C ranged from 53.891% to 77.934% while the processed samples stored at 30 – 33$^{o}$C recorded a range of 50.655% to

75.964%. With regard to refrigerator storage, *Termitomyces* spp baked and sun dried recorded the highest carbohydrate value of 77.934% while *Termitomyces* spp blanched and sun dried recorded the lowest carbohydrate value of 53.891%. For *P. ostreatus*, samples that was blanched and sun dried and packaged in rubber bag recorded the lowest carbohydrate value of 64.535%.

Fat content varied in the processed mushrooms. For refrigerator storage, *Termitomyces* spp sun dried and packaged in rubber bag contained the highest value of 7.606% and the lowest of 0.154% was found in *Termitomyces* spp sun dried and packaged in plastic container. For room storage, *Termitomyces* spp sun dried and packaged in rubber bag recorded the highest fat value of 8.111% while *P. ostreatus* blanched and sun dried and packaged in plastic container recorded the lowest fat value of 0.120% (Table 4.9). From the results obtained, rubber bag package maintain fat content better than the plastic container package. According Csapo and Vargane (2011) fat oxidation increase with increasing moisture content in mushrooms. The moisture content of the mushrooms packaged in rubber bags reduced considerably over the storage period. This might accounted for reduction in fat oxidation hence fat value was maintained better in this packaging material.

Mushrooms are rich sources of mineral elements (Rai and Arumuganathan, 2008). Zinc, calcium and phosphorus were the mineral elements studied. It was observed that the packaging materials and the prevailing conditions in the storage environment had little or no influence on the minerals composition of the processed mushrooms (Table 4.8 and 4.9). The ascorbic acid content for both storage conditions also present similar values.

However, the ash values for the processed mushrooms after 20 days period for the two storage environments showed significant changes. For refrigerator storage, the values of ash content range from 8.021% to 25.387% while room storage recorded a range of 7.879% to 25.031%. *Termitomyces* spp blanched and sun dried recorded the highest ash value of 25.387% while *P. ostreatus* baked and sun dried the lowest value of 8.021% for samples stored at 4$^{o}$C. For samples stored at temperature of 30 – 33$^{o}$C, *Termitomyces* spp blanched and sun dried recorded the highest value of 25.031% while *P. ostreatus* baked and sun dried recorded the lowest of 7.879%. The higher ash value in blanched products could be attributed to salt content in the mushroom.

Sun dried Oyster Mushroom and mud oven dried Wild Mushroom have higher consumer assessment compared to the rest of the processing techniques. This observation could be due to satisfactory taste the consumers have had over the years with these processing methods compared to other methods. The sensory analysis indicated that sun dried oyster mushroom was preferred by the panelists to any other processed samples. They explained that the texture, aroma and appearance were better than the rest of the samples. According to Rai and Arumuganathan (2008) sun dried oyster mushroom regained texture and flavour better than any other processing techniques. They however suggested that further drying should be employed to reduce the moisture content to 7% to prevent spoilage during storage. The panelists disliked for appearance, size and aroma of the blanched and sun dried oyster mushroom could be attributed to the brown colour of the sample caused by maillard reactions (Oei, 2003). Contrary, blanched and sun dried oyster mushroom had better taste assessment. This could be due to taste enhancement obtained when the mushroom was dipped into salt solution. Bernaś *et al*. (2006) reported that mushroom dipped in salt solution improved taste but had negative effect on some of its nutrients. The panelist disliked for texture of mud oven dried, and taste and aroma of baked and sun dried oyster mushroom could be due to the brown colour they observed of the products. This brown colour might be due to enzymatic and non-enzymatic browning reactions (Byung, 2004). These reactions had negative consumer assessment on processed product (Rai and Arumuganathan, 2008).

Different trends were observed in Table 4.11. Mud oven dried *Termitomyces* spp had better consumer assessment than any of the processed sample. This might be due to the resistant of the mushroom to maillard browning (Byung, 2004). Low appearance, texture and size scored by the panelists for blanched and sun dried *Termitomyces* spp; and low taste and aroma for baked and sun dried *Termitomyces* spp could be attributed to the temperature effect on the product. Byung (2004) asserted that blanching mushrooms in brine solution before drying as well as baking and drying them facilitate enzymatic browning.

# CHAPTER SIX

## 6.0 CONCLUSION AND RECOMMENDATION

### 6.1 Conclusion

- The research revealed that mishandling, untimely harvesting and improper harvesting methods of wild mushrooms reduce its market value and provide medium for pests and diseases attack.
- The results from the study showed that processed mushrooms are rich in proteins, carbohydrates, minerals, vitamins and good fats.
- The various processing techniques used revealed that mud oven drying of the mushrooms provides the best result by maintaining the nutrient composition in the mushrooms better than the rest of the processing methods.
- Blanching (in salt solution) and sun drying method maintain mushroom colour but had negative effect on the nutrient composition of the processed product as most of the nutrients might have leached into the salt solution.
- Sun drying was found to be easiest and cheapest method in terms of labour involvement. *P. ostreatus* sun dried maintained its original colour and better flavour but had higher moisture content hence further drying in oven at a lower temperature for a minimum of 2 hours to reduce the moisture content to about 8% is required. The rest of processed product produced creamy and brown colour.
- It was also observed that mud oven drying of mushroom for 2 hours at 80$^{o}$C reduced the initial moisture content of 85% to 10% hence provided the best method for processing and storing the processed mushrooms for a longer period without deterioration. Processed products stored in refrigerator provides the best

means of storage than those stored in room as the moisture content of mushrooms stored in refrigerator at 4°C reduced considerably to about 4% or lower during the 20 days storage period. This was due to loss of moisture by the product to the storage environment. However, the change in moisture content of the product in the two storage conditions showed insignificant differences in values. It was also worth noting that the lower the moisture content the higher the solid content and the longer the storage period for future use. High moisture content facilitate mushroom rot and microbial attack.

- It was revealed from the results that due to the permeability of the packaging material to moisture coupled with low relative humidity in the storage environment, moisture moves easily from the product to the environment. This was manifested in the values obtained for moisture content for the 20 days storage period.
- The study also revealed that sun dried oyster mushroom and mud oven dried wild mushroom have high consumer assessment compared to the rest of the processing techniques.

## 6.2 Recommendation

- Further research should be carried out to identify what might have accounted for the loss in nutritional composition of blanched mushrooms in 20g of salt solution for 15 minutes. Several literatures agreed on this assertion but failed to explain the chemistry behind this loss.
- Research should be carried out to ascertain whether low mud oven drying temperatures of mushrooms for longer period could influence the nutritional content of the product.

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# APPENDICES

## APPENDIX 1 Questionnaire for farmers to assess their methods of harvesting wild mushrooms and ways of reducing postharvest losses in wild mushrooms

This questionnaire is designed to solicit information for purely academic purpose. This is to enable KOKOTI GAMELI KWABLA, a final year student of the University of Ghana, Legon to complete his thesis on the Research Topic: Assessing the effect of processing techniques on storage, physical attributes and nutritional composition of Wild Mushrooms (*Termitomyces* spp) and Oyster Mushroom (*Pleurotus ostreatus*) in pursuant of a Master of Philosophy in Crop Science.

Dear Respondent,

I would be grateful if you could give your response to each of the following questions in connection with the above-mentioned study.

***Instructions****: Please write answers for your responses on the line provided and tick where appropriate.*

A. **Background Information**

1. Age (yrs.): 10 – 20 ☐ 20 – 30 ☐ 30 – 40 ☐ 40 and above ☐
2. Sex: Female ☐ Male ☐
3. Marital status: Single ☐ Married ☐ Widowed ☐
4. Main occupation: ……………………………………………..
5. Secondary occupation: ………………………………..............
6. Number of years of harvesting wild mushroom………………

   Contact number (if any)……………………..

B. **Harvesting of mushroom**

7. At what stage is ideal for harvesting wild mushrooms?

When the veil has not opened ☐ When the veil is about to open ☐

When the veil has opened ☐

8. What time is ideal for harvesting mushroom?

Early morning ☐ Afternoon ☐ Late afternoon ☐ Evening ☐

Explain your choice of time

……………………………………………………………………………………………

9. How are the mushrooms harvested?

Pulling them with hand ☐ Digging around them with cutlass and pulling them ☐

Digging them up with hoe ☐ Specify any other method if not included………………..

……………………………………………………………………

10. How much volume of mushrooms is collected per day?

1kg ☐ 2kg ☐ 3kg ☐ 4kg ☐ 5kg or more ☐

**C. Postharvest management of mushrooms**

11. How many times do you harvest the mushroom in the colony each day?

1 time ☐ 2 times ☐ 3 times ☐ 4 times ☐ 5 times or more ☐

12. How are the mushrooms handled after harvesting from the field?

Kept in an open bowl ☐ Kept in a bowl and covered ☐

Tied with thread and held in the hand ☐ Specify any other handling procedure

…………………………………………………………………………………………..

13. How are the fresh mushrooms pretreated before sale?

Wash with clean water ☐ Wash with brine water ☐ None of these ☐

14. How are the fresh mushroom packaged?

    In a plastic containers ☐ In a rubber bags ☐

    Tied with thread ☐ No packaging done ☐

15. What happen to fresh mushrooms that are unsold?

    Sun drying them ☐ Baking them ☐ Grilling them ☐

    Baking and sun drying them ☐ Steaming them ☐

    Specify other treatment (s) if not included………………………………………………

**D. Postharvest losses of mushrooms**

16. What volume of mushrooms are sold daily from what is collected?

    1 kg ☐ 2 kg ☐ 3 kg ☐ 4 kg ☐ 5 kg or more ☐

17. What volume of mushrooms are left unsold daily?

    0.1 kg ☐ 0.2 kg ☐ 0.3 kg ☐ 0.4 kg ☐ 0.5 kg or more ☐

18. What quantities of mushrooms (in kg) go waste after harvesting from the field?

    ……………………………………………………………………………………

19. What are major cause of losses in the harvested mushrooms?

    Mishandling of mushrooms ☐ Pests attack of mushrooms ☐

    Sun scorch ☐ Diseases attack of mushrooms ☐

    Specify if any other cause (s) is/are not included……………………………………..

    ……………………………………………………………

**E. Ways of reducing postharvest losses of mushrooms**

20. How can cap and stalk losses be reduced?

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

21. In your own words explain briefly ways of minimizing losses in harvested mushrooms

    ………………………………………………………………………

*Thank You*

**APPENDIX 2 Analysis of proximate composition of cultivated and wild fresh mushrooms (per 100g sample)**

Analysis of variance

Variate: ASCORBIC_ACID

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| TRT | 1 | 0. | 0. | | |
| Residual | 4 | 0. | 0. | | |
| Total | 5 | 0. | | | |

Tables of means

Variate: ASCORBIC_ACID

Grand mean 0.01

| TRT | OYSTER MUSHROOM | TERMITOMYCES |
|---|---|---|
| | 0.01 | 0.01 |

Standard errors of means

| Table | TRT |
|---|---|
| rep. | 3 |
| d.f. | * |
| e.s.e. | 0.000 |

Standard errors of differences of means

| Table | TRT |
|---|---|
| rep. | 3 |
| d.f. | * |
| s.e.d. | 0.000 |

Least significant differences of means (5% level)

| Table | TRT |
|---|---|
| rep. | 3 |
| d.f. | * |
| l.s.d. | * |

**APPENDIX 3 Analysis of proximate composition of processed mushrooms (per 100g sample)**

Analysis of variance

Variate: ASCORBIC_ACID

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| TRT | 7 | 5.727E-02 | 8.181E-03 | 8181.43 | <.001 |
| Residual | 16 | 1.600E-05 | 1.000E-06 | | |
| Total | 23 | 5.729E-02 | | | |

Tables of means

Variate: ASCORBIC_ACID

Grand mean 0.06100

| TRT | OMB&D | OMBL&D | OMEOD | OMSD | TB&D | TBL&D | TEOD |
|---|---|---|---|---|---|---|---|
| | 0.04300 | 0.02200 | 0.18300 | 0.03500 | 0.04300 | 0.02800 | 0.07700 |

| TRT | TSD |
|---|---|
| | 0.05700 |

Standard errors of means

| Table | TRT |
|---|---|
| rep. | 3 |
| d.f. | 16 |
| e.s.e. | 0.000577 |

Standard errors of differences of means

| Table | TRT |
|---|---|
| rep. | 3 |
| d.f. | 16 |
| s.e.d. | 0.000816 |

Least significant differences of means (5% level)

| Table | TRT |
|---|---|
| rep. | 3 |
| d.f. | 16 |
| l.s.d. | 0.001731 |

**APPENDIX 4 Analysis of proximate composition of processed mushrooms stored at 4°C in rubber bags and plastic containers after 10 days (per 100g sample)**

Analysis of variance

Variate: ASH

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| TRT | 15 | 1.468E+03 | 9.787E+01 | 1.402E+07 | <.001 |
| Residual | 32 | 2.233E-04 | 6.979E-06 | | |
| Total | 47 | 1.468E+03 | | | |

*Message: the following units have large residuals.*

*units* 17 -0.00533 s.e. 0.00216

Tables of means

Variate: ASH

Grand mean 11.83106

| TRT | OMB&D(P) | OMB&D(R) | OMBL&D(P) | OMBL&D(R) | OMEOD(P) | OMEOD(R) | OMSD(P) |
|---|---|---|---|---|---|---|---|
| | 7.70600 | 8.69033 | 18.85833 | 18.52667 | 9.71933 | 9.53100 | 8.59400 |

| TRT | OMSD(R) | TB&D(P) | TB&D(R) | TBL&D(P) | TBL&D(R) | TEOD(P) | TEOD(R) |
|---|---|---|---|---|---|---|---|
| | 7.56800 | 9.46733 | 8.30433 | 24.86233 | 21.86000 | 8.93033 | 8.07200 |

| TRT | TSD(P) | TSD(R) |
|---|---|---|
| | 11.05200 | 7.55500 |

Standard errors of means

| Table | TRT |
|---|---|
| rep. | 3 |
| d.f. | 32 |
| e.s.e. | 0.001525 |

Standard errors of differences of means

| Table | TRT |
|---|---|
| rep. | 3 |
| d.f. | 32 |
| s.e.d. | 0.002157 |

Least significant differences of means (5% level)

| Table | TRT |
|---|---|
| rep. | 3 |
| d.f. | 32 |
| l.s.d. | 0.004394 |

**APPENDIX 5 Analysis of proximate composition of processed mushrooms stored at 30 – 33°C in rubber bags and plastic containers after 10 days (per 100g sample)**

Analysis of variance

Variate: ASCORBIC_ACID

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| TRT | 15 | 1.02005933 | 0.06800396 | 3290.51 | <.001 |
| Residual | 32 | 0.00066133 | 0.00002067 | | |
| Total | 47 | 1.02072067 | | | |

Tables of means

Variate: ASCORBIC_ACID

Grand mean 0.18367

| TRT | OMB&D(P) | OMB&D(R) | OMBL&D(P) | OMBL&D(R) | OMEOD(P) | OMEOD(R) | OMSD(P) |
|---|---|---|---|---|---|---|---|
| | 0.12400 | 0.12767 | 0.06500 | 0.06800 | 0.54400 | 0.54900 | 0.11300 |

| TRT | OMSD(R) | TB&D(P) | TB&D(R) | TBL&D(P) | TBL&D(R) | TEOD(P) | TEOD(R) |
|---|---|---|---|---|---|---|---|
| | 0.10967 | 0.12033 | 0.11500 | 0.09033 | 0.09133 | 0.23533 | 0.24033 |

| TRT | TSD(P) | TSD(R) |
|---|---|---|
| | 0.17467 | 0.17100 |

Standard errors of means

| Table | TRT |
|---|---|
| rep. | 3 |
| d.f. | 32 |
| e.s.e. | 0.002625 |

Standard errors of differences of means

| Table | TRT |
|---|---|
| rep. | 3 |
| d.f. | 32 |
| s.e.d. | 0.003712 |

Least significant differences of means (5% level)

| Table | TRT |
|---|---|
| rep. | 3 |
| d.f. | 32 |
| l.s.d. | 0.007561 |

**APPENDIX 6 Analysis of proximate composition of processed mushrooms stored at 4°C in rubber bags and plastic containers after 20 days (per 100g sample)**

Analysis of variance

Variate: ASCORBIC_ACID

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| TRT | 15 | 1.09322281 | 0.07288152 | 3357.31 | <.001 |
| Residual | 32 | 0.00069467 | 0.00002171 | | |
| Total | 47 | 1.09391748 | | | |

Tables of means

Variate: ASCORBIC_ACID

Grand mean 0.19560

| TRT | OMB&D(P) | OMB&D(R) | OMBL&D(P) | OMBL&D(R) | OMEOD(P) | OMEOD(R) | OMSD(P) |
|---|---|---|---|---|---|---|---|
| | 0.12967 | 0.13033 | 0.06433 | 0.06533 | 0.55033 | 0.54833 | 0.12433 |

| TRT | OMSD(R) | TB&D(P) | TB&D(R) | TBL&D(P) | TBL&D(R) | TEOD(P) | TEOD(R) |
|---|---|---|---|---|---|---|---|
| | 0.12233 | 0.12833 | 0.12700 | 0.08533 | 0.08600 | 0.30033 | 0.32033 |

| TRT | TSD(P) | TSD(R) |
|---|---|---|
| | 0.17533 | 0.17200 |

Standard errors of means

| | |
|---|---|
| Table | TRT |
| rep. | 3 |
| d.f. | 32 |
| e.s.e. | 0.002690 |

Standard errors of differences of means

| | |
|---|---|
| Table | TRT |
| rep. | 3 |
| d.f. | 32 |
| s.e.d. | 0.003804 |

Least significant differences of means (5% level)

| | |
|---|---|
| Table | TRT |
| rep. | 3 |
| d.f. | 32 |
| l.s.d. | 0.007749 |

**APPENDIX 7 Analysis of proximate composition of processed mushrooms stored at 30 – 33ºC in rubber bags and plastic containers after 20 days (per 100g sample)**

Analysis of variance

Variate: ASCORBIC_ACID

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| TRT | 15 | 9.631E-01 | 6.420E-02 | 29632.70 | <.001 |
| Residual | 32 | 6.933E-05 | 2.167E-06 | | |
| Total | 47 | 9.631E-01 | | | |

*Message: the following units have large residuals.*

| | | | |
|---|---|---|---|
| *units* 36 | -0.00300 | s.e. | 0.00120 |
| *units* 47 | 0.00367 | s.e. | 0.00120 |

Tables of means

Variate: ASCORBIC_ACID

Grand mean 0.19348

| TRT | OMB&D (R) | OMB&D(P) | OMBL&D(P) | OMBL&D(R) | OMEOD(P) | OMEOD(R) | OMSD (R) |
|---|---|---|---|---|---|---|---|
| | 0.14033 | 0.13800 | 0.06800 | 0.07033 | 0.52033 | 0.56000 | 0.15333 |

| TRT | OMSD(P) | TB&D (P) | TB&D (R) | TBL&D (P) | TBL&D (R) | TEOD (P) | TEOD (R) |
|---|---|---|---|---|---|---|---|
| | 0.15033 | 0.12200 | 0.12333 | 0.09833 | 0.09400 | 0.26233 | 0.26033 |

| TRT | TSD (P) | TSD (R) |
|---|---|---|
| | 0.16933 | 0.16533 |

Standard errors of means

| Table | TRT |
|---|---|
| rep. | 3 |
| d.f. | 32 |
| e.s.e. | 0.000850 |

Standard errors of differences of means

| Table | TRT |
|---|---|
| rep. | 3 |
| d.f. | 32 |
| s.e.d. | 0.001202 |

Least significant differences of means (5% level)

| Table | TRT |
|---|---|
| rep. | 3 |
| d.f. | 32 |
| l.s.d. | 0.002448 |

**APPENDIX 8 Questionnaire for mushroom farmers and consumers in Hohoe and Kpelezo communities to evaluate consumer acceptability of two dried species of mushrooms**

This questionnaire is designed to solicit information for purely academic purpose. This is to enable KOKOTI GAMELI KWABLA a final year student of the University of Ghana, Legon complete his thesis on the Research Topic: Assessing the effect of processing techniques on storage, physical attributes and nutritional composition of Wild Mushrooms (*Termitomyces* spp) and Oyster Mushroom (*Pleurotus ostreatus*) in pursuant of Master of Philosophy Crop Science.

Dear Respondent,

I would be grateful if you could give your response to each of the following questions in connection with the above-mentioned study.

***Instructions****: Please write numbers of your rating in the boxes and sentences on the line provided and tick where appropriate.*

**A. Background Information**

1. Name (optional)………………………………………… 2. Age (yrs.)………
3. Sex: Female ☐ Male ☐
4. Marital status: Single ☐ Married ☐ Widowed ☐
5. Number of years in production and/or harvesting of wild and oyster mushroom………………
6. Contact number (if any)……………………..

**B. Consumer Evaluation of Dried Mushrooms**

7. Rate the fruity aroma for the dried mushrooms

   (*dislike/3; neither/6; like/10*)

| | | | |
|---|---|---|---|
| | | | |
| Sun dried mushroom | | | |
| Baked and dried mushroom | | | |
| Blanched and dried mushroom | | | |
| Mud oven dried mushroom | | | |

8. Which colour of the dried mushroom do you prefer?

   (*dark brown/10; brown/20; cream/30*)

| | | | |
|---|---|---|---|
| | | | |
| Sun dried mushroom | | | |
| Baked and dried mushroom | | | |
| Blanched and dried mushroom | | | |
| Mud oven dried mushroom | | | |

9. Which texture of dried mushroom do you like?

(*rough/5; rough and tender/10; smooth and tender/15*)

| | | | |
|---|---|---|---|
| Sun dried mushroom | | | |
| Baked and dried mushroom | | | |
| Blanched and dried mushroom | | | |
| Mud oven dried mushroom | | | |

10. Rate the size of the dried mushroom

(*too small/6; small/12; large/20*)

| | | | |
|---|---|---|---|
| Sun dried mushroom | | | |
| Baked and dried mushroom | | | |
| Blanched and dried mushroom | | | |
| Mud oven dried mushroom | | | |

11. How will you rate the taste of the dried mushroom

(*it is tasteless/8; it holds ones tongue/16; it is tasty/25*)

| | | | |
|---|---|---|---|
| Sun dried mushroom | | | |
| Baked and dried mushroom | | | |
| Blanched and dried mushroom | | | |
| Mud oven dried mushroom | | | |

**C. Improvement of Physical Attribute**

12. How should the taste of the mushroom be improve?

……………………………………………………..

13. Will the colour of the mushroom influence its prize?

Yes ☐ No ☐

If yes,

explain…………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

**D. Package Material Acceptability**

14. Which packaging of the dried mushroom will you prefer?

Rubber bag ☐ Plastic containers ☐

Explain your choice

**APPENDIX 9 Table of Scoring**

| **Attributes** | **Max-Score** | **Sample-1** (SD) | **Sample-2** (B&D) | **Sample-3** (BL&D) | **Sample-4** (MOD) |
|---|---|---|---|---|---|
| Appearance | 30 | | | | |
| Texture | 15 | | | | |
| Size | 20 | | | | |
| Taste | 25 | | | | |
| Aroma | 10 | | | | |
| Total score | 100 | | | | |