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Development of maize-based composite flour enriched with mushroom for complementary feeding

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DEVELOPMENT OF MAIZE-BASED COMPOSITE FLOUR ENRICHED WITH MUSHROOM FOR COMPLEMENTARY FEEDING

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A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Master's in Life Sciences of the Nelson Mandela African Institution of Science and Technology

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ABSTRACT

Complementary foods based on habitual cereals such as maize have been linked with the promotion of under-nutrition in young children. This study aimed at improving the nutritional value of maize flour commonly used as a bulk ingredient in complementary foods using oyster mushroom (*Pleurotus ostreatus*). Drying methods for fresh mushroom was done by using oven, sun and solar drier. Flour made of well cleaned and solar-dried oyster mushroom was blended with maize flour at 0% (control), 30%, 40% and 50%. Solar drying was the best method in terms of nutrient retention of oyster mushroom, product hygiene and safety. Flour blend of 30%, 40% and 50% oyster mushroom improved the protein content from 8.63% to 18.20%, 8.63% to 20.37% and 8.63% to 22.75%, respectively. The increase in ash and fiber content ranged between 82.52% to 84.16% and 50.69% to 58.35%, respectively. Mineral content of formulated flour blends was improved from 62.89% to 64.72% (iron); 7.63% to 22.69 % (zinc); 77.48% to 78.02% (calcium) and 67.55% to 67.64% (potassium). The flour blend of 50% oyster mushroom was the best as it was rich in nutrients compared to flour blends comprised of 30 and 40% oyster mushroom. Sensory scores of porridge prepared from the three formulated flour blends indicated good acceptance. This study recommends blending oyster mushroom with maize flour to improve their nutritional content of formulated flour blend for young children who rely on maize porridge as their complementary food.

DECLARATION

I, Prisca Siyame, do hereby declare to the Senate of the Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been presented nor submitted for degree award in any other institution.

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CERTIFICATION

The undersigned certify that they have read the dissertation titled "Development of maize-based composite flour enriched with mushroom for complementary feeding" and recommend for acceptance in fulfillment for the requirements for the award of Master's in Life Sciences of the Nelson Mandela African Institution of Science and Technology.

Dr. Neema Kassim		09/08/2021
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DEDICATION

This dissertation is dedicated to my beloved parents Mr. and Mrs. Elias Siyame who laid down the foundation of my education. Your endless love, support, worthy heart and commitment in my life will never be forgotten.

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LIST OF ABBREVIATIONS AND SYMBOLS

AOAC	Association of Official Analytical Chemists
cfu	Colony Forming Unit
g	Gram
Kcal	Kilocalories
Kg	Kilogram
Mg	Milligram
Ml	Millilitre
NCDs	Non Communicable Disease
TNNS	Tanzania National Nutrition Survey
Tsh	Tanzanian Shilling
Uv	Ultraviolet
W/W	Weight by Weight
Wb	Wet Basis

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

Maize (*Zea mays L.*) is one of the essential annual cereal crops used as a staple food after rice and wheat worldwide (Rouf-Shah *et al*., 2016). Maize serves as the vital basis of food security for millions of people in most developing countries, particularly in Sub-Saharan Africa (Ai & Jane, 2016). In Tanzania, maize serves as the primary staple food whose cultivation covers the largest area of all cultivated land (Ngurumwa, 2016). The maize consumption varies from fine maize flour blended with water to produce thin or stiff porridges, sweet composite bread, cakes, cookies and boiling or roasting the fresh maize to make snacks and savoury dishes (Nuss *et al*., 2012). Furthermore, maize is used as the main ingredient of complementary food for young children alone or in combination with several types of cereals like sorghum, wheat and millet (Abeshu *et al*., 2016).

White maize, predominantly used in Tanzania, is regarded as nutritionally deficient among cereals. They contain low protein levels (9.3%) than their counterparts, such as wheat and sorghum, whose protein content is above 10% (Nuss & Tanumihardjo, 2010). Furthermore, white maize also lacks the essential amino acids, lysine and tryptophan and are devoid of vitamin C and B group vitamins. They are also deficient in macro and trace minerals such as iron, zinc, calcium, magnesium, potassium and phosphorus (Nuss & Tanumihardjo, 2010). Despite its low protein and micronutrient levels, maize is the main ingredient in complementary foods for children under five years of age in Tanzania (Muhimbula & Issa-Zacharia, 2010). Consequently, the use of maize as the main constituent of complementary food has increased the under-nutrition severity, presumably due to the grain's low nutritional profile.

To date, Tanzania is among the leading countries in Sub-Saharan Africa with a high rate of under-nutrition, occurring in both forms of underweight, wasting and stunting (Tanzania National Nutrition Survey [TNNS], 2018). Stunting is the major form of under-nutrition to young children in Tanzania, accounting for 31.8% of all cases (TNNS, 2018). The drivers of dietary-related non-communicable diseases (NCDs), including under-nutrition, are mainly unhealthy diets for both children and the elderly. Nonetheless, Tanzania is home to a wide variety of indigenous and non-indigenous crops, including pulses, nuts, cereals, fruits and vegetables, which contain essential nutrients that contribute to healthy and productive lives.

Therefore, improving the nutritional value of habitual cereal-based complementary foods such as maize using other existing crops could promote food diversification during the complementary feeding period.

Mushrooms are widely reported as ingredients of various complementary foods to promote indigenous foods as a critical contributor to nutritious complementary food. Ikujenlola and Ogunba (2018) studied mushrooms as a nutritional supplement in a blend of quality protein maize and sesame - complementary food. Similarly, Mallikarjuna *et al*. (2013) recommended using mushrooms as protein supplements to populations largely dependent on cereal diets. Aishah and Rosli (2013) reported that mushrooms powder is used in carbohydrate-based products to enhance nutrient composition without affecting sensory acceptance. Furthermore, Deepalakshmi and Sankaran (2014) revealed that oyster mushrooms' use improved cereal-based foods' nutrient content for complementary feeding due to their enriched good nutritional profile.

Oyster mushrooms commonly known as *Pleurotus species,* are among the most common types of cultivated mushrooms in the world (Sánchez, 2010). This type of mushroom scores the second position among the vital mushrooms grown worldwide as they contribute approximately 2.7% of entire fresh mushrooms produced (Girmay *et al.,* 2016). Oyster mushroom is highly nutritious as it contains a superior quality protein with entirely all essential amino acids. Besides, lysine and leucine are plentiful and always deficient in many staple cereal foods (Valverde *et al*., 2015). Additionally, the oyster mushrooms comprise of vital minerals such as iron, zinc, calcium, potassium, magnesium, copper and phosphorus in a substantial amount. Mushrooms also contain abundant essential vitamins, including B group vitamins, particularly thiamine, riboflavin, nicotinic acid, folic acid, pyridoxine, pantothenic acid and cobalamin (Parul & Asha, 2014). Studies have revealed that mushrooms offer a diversity of flavour, texture and nutrients (Rahi & Malik, 2016).

Despite the mushrooms' potential as an excellent source of vitamins and minerals with various health and nutritional benefits, it is still underutilized in combating undernutrition, particularly stunting and micronutrient deficiency common in Tanzania. Thus, this study aimed at improving the nutritional value of maize-based flour which is habitually used as the main ingredient in complementary foods by using oyster mushroom (*Pleurotus ostreatus*).

1.2 Statement of the Problem

The use of low nutrient density cereal-based complementary foods has been linked with the promotion of children under-nutrition. In Tanzania, many interventions have been done to mitigate the widespread of under-nutrition but the problem is still prevailing in all forms of wasting, stunting and underweight while stunting being the major form as 31.8% of young children are short for their age (TNNS, 2018). The dependency on cereal-based traditional complementary foods mainly maize meal porridge has been identified as the major cause of all forms of under nutrition to young children as they are characterized by low levels of protein and micronutrients (Muhimbula & Issa-Zacharia, 2010). This call for an action to formulate the home-based traditional complementary foods enriched with nutritious underutilized foods like mushrooms in order to fill the low nutrient intake gap throughout the complementary feeding period.

Mushrooms are potential sources of superior quality proteins (19 - 35%) with all essential amino acids which are distributed in good concentrations. Thus, the inclusion of mushroom in cereal diets will aid in lessening the lysine and leucine deficiencies common in many staple cereal foods (Ahmed *et al*., 2016). Besides, mushrooms are comprised of important minerals required in the human body such as iron, zinc, calcium, magnesium, potassium, phosphorus and trace elements like selenium and copper (Radulescu *et al*., 2010). Furthermore, mushrooms are excellent sources of vitamin D and B group vitamins such as riboflavin, thiamine, niacin, folate and pantothenic acid (Afetsu, 2014). Total fat content in mushrooms is very low whereas it contains the maximum quantity of polyunsaturated fatty acids (72 to 85%) as compared to the fat content basically due to linoleic acid (Kalač, 2009).

Regardless of the abundant nutritional benefits, the utilization of mushrooms in complementary foods to lessen under-nutrition to young children is limited. Thus, this study aimed at formulating maize-based composite flour enriched with mushroom for complementary feeding.

1.3 Rationale of the Study

There are numerous interventions reported to mitigate the widespread of under-nutrition in the country. Despite these efforts, the problem is still prevailing in all forms of wasting, stunting and underweight (TNNS, 2018). The latter is presumed to be caused by over dependency on cereal-based traditional complementary foods mainly maize meal porridge to young children (Muhimbula & Issa-Zacharia, 2010).

Mushrooms are crucial ingredients of various complementary formulations that promote consumption of indigenous foods. Consequently, mushrooms critically contribute to nutritious complementary food to young children. Oyster mushroom is rich in plentiful superior quality nutrients such as protein, minerals and vitamins some of which are deficient in many staple cereal foods

Despite the mushrooms' potential as an excellent source of crucial nutrients and numerous health and nutritional benefits, it is still underutilized in curbing the stunting and micronutrient deficiency most common in Tanzania. This highlights the need for formulating home-based traditional complementary diets enriched with nutritious underutilized foods such as mushrooms to fill the low nutrient intake gap throughout the complementary feeding period. The present study will enlighten the improvement of nutritional value of habitual cereal-based complementary foods such as maize using existing high value crops, such as oyster mushrooms.

1.4 Research Objectives

1.4.1 General Objective

To develop maize-based composite flour enriched with mushroom for complementary feeding.

1.4.2 Specific Objectives

(i) To optimize drying conditions for mushrooms.

(ii) To optimize the mixing ratio of mushroom and maize for composite flour rich in nutrients.

(iii) To conduct microbial safety of the maize-mushroom composite flours.

(iv) To assess consumer acceptability of the porridges made from the maize-mushroom composite flours.

1.5 Research Questions

(i) Which conditions are suitable for optimal drying of mushrooms?

(ii) Which optimal mixing ratio of maize to mushroom offers the best composite flour rich in nutrients?

(iii) What is microbial safety of the maize-mushroom composite flour?

(iv) Are the porridges made from maize-mushroom composite flour acceptable to consumers?

1.6 Significance of the Study

The results of this study will provide critical information to the community on enriching the maize-based flour using a very nutritious locally available food, oyster mushroom (*Pleurotus ostreatus*). Additionally, the information obtained from this study will advocate the use of oyster mushroom in complementary food formulations. Researchers will be stimulated to pay attention to the underutilized nutritious food such as oyster mushroom. Furthermore, the study will also increase interest in oyster mushroom cultivation in large scale.

1.7 Delineation of the Study

This study focused on development of maize-based composite flour enriched with mushroom for complementary feeding. In our understanding, various types of mushrooms are grown in Tanzania. Nonetheless, the present study utilized specific cultivar of mushroom known as *oyster mushroom* (*Pleurotus ostreatus*). The latter were chosen due to their nutritional properties and numerous health benefits. Previous studies may have reported formulations of oyster mushroom with cereal-based complementary foods. However, differences in agro-climatic conditions could potentially influence differences in nutritional compositions of cultivated oyster mushrooms from different geographical locations. Therefore, findings from previous results on role of oyster mushroom in nutritional composition of formulated composite flours cannot be extrapolated.

CHAPTER TWO

LITERATURE REVIEW

2.1 Maize Overview in Tanzania

Maize is the best vital cereal crop of substantial economic-wise substituting sorghum and millet. It has been reported by De Groote *et al*. (2013) that the present production of maize worldwide is 10.14 tons of billion metrics. The production of maize in Africa is reported to be approximately 7% of the whole world's production. In Tanzania, maize is regarded as the basic crop and is cultivated in almost all agro-ecological areas within the country (Ranum *et al*., 2014). According to Suleiman and Kurt (2015), Tanzania scored the top 25^{th} position in the production of maize worldwide hence became the main producer of maize in sub-Saharan Africa. Generally, in the past 25 years, the production of maize has increased to 4.6% annually. Maize has been recognized as the vital crop in promoting the production of food earnings, reduction of poverty and securing of food (Tui *et al*., 2013).

As in many developing countries, likewise in Tanzania, maize is mainly utilized as human food which is consumed in both urban and rural areas (Oladejo & Adetunji, 2012). Maize contributes about 31% of the overall food production and 75% of the total cereal intake in Tanzania. Maize provides 34 - 36% of the mean calorie consumption per day (Zorya *et al*., 2011). The consumption of maize varies from fine maize flour blended with water to produce thin or stiff porridges, infant food, sweet composite bread, cakes, cookies and boiling or roasting the fresh maize to produce snacks and savory dishes (Nuss *et al*., 2012).

2.2 Nutritional Composition of Maize

The significance of maize is concentrated on the presence of a considerable amount of carbohydrate content approximately 70% of the total weight making it the main source of energy but also maize contains protein, fats and vitamins though they are in limited amounts (Chaudhary *et al*., 2014). Furthermore, maize constitutes of small amounts of bioactive compounds like phenolic compounds and antioxidants which differ from one type of maize to another (Singh *et al*., 2014). The quantity of essential macro and micronutrients in maize is very unsatisfactory as they lack essential amino acids such as lysine and tryptophan as well as vitamin C and B group vitamins, carotenoids and minerals such as iron, calcium and zinc thus termed as nutritionally poor (Chaudhary *et al*., 2014).

2.3 Processing of Maize Grains to Flour

For years, the processing of maize grains involves milling into fine flour which is used in different ways. Comparable with other cereals, the great quantities of micronutrients are intense in the surface layers (brans) of the maize grain (Ranum *et al*., 2014). On the other hand, the maize brans have high anti-nutrients contents which can be minimized through the dehulling process. Therefore, the milling process is preceded by the removal of the outer layers (brans) to reduce the anti-nutrients present in the maize as well as improving the flavor of maize flour products. The process of removing the maize brans affect negatively the levels of nutrients in the maize flour as it removes the important nutrients such as vitamins and minerals. This makes maize to be among the major contributor of micronutrient deficiency to young children due to its dependency on maize-based complementary food (Muhimbula & Issa-Zacharia, 2010).

Table 1: Nutritional Composition of Maize (white variety)

Proximate composition (per 100 g)		Vitamins (per 100 g)	
Protein (g)	8.1	Thiamine (mg)	0.4
Fat (g)	3.6	Riboflavin (mg)	0.2
Carbohydrate (g)	76.9	Niacin (mg)	3.6
Fiber (g)	7.3	Vitamin B6 (mg)	0.3
Energy (Kcal)	362	Pantothenic acid (mg)	0.4
		Folate (µg)	25
		Vitamin E (µg)	1.0
Minerals (mg)		Amino Acids (mg)	
Magnesium	127	Tryptophan	19
Potassium	287	Threonine	101
Sodium	35	Isoleucine	96
Iron	3.5	Leucine	329
Zinc	1.8	Lysine	75
Copper	0.2	Methionine	56
Manganese	5	Cysteine	48
Calcium	6	Phenylalanine	132
Phosphorus	241	Tyrosine	109
		Valine	136
		Arginine	134
		Histidine	82

Tanzania Food Composition Table; Lukmanji and Hertzmark (2008)

2.4 Mushroom Overview in Tanzania

Mushrooms belong to higher fungi with fruiting bodies very different from plants as they do not contain green chlorophyll required to produce their own food through the photosynthesis process. More than 100 edible mushrooms have been recognized in Tanzania (Harkonen *et al*., 2003). The cultivation of mushroom in Tanzania is succeeding day after day as more than 4000 smallholders from 10 regions namely Pwani, Kagera, Arusha, Mbeya, Dar es salaam and others are growing mushrooms leading to the total production of approximately 960 tons per year with an estimated value of Tsh. 3840 million (Kivaisi, 2007).

Furthermore, oyster mushrooms (*Pleurotus species*) are the succeeded mushrooms cultivated in Tanzania though, attempts of cultivating other mushroom species like *Agaricus bisporus* (button mushroom) as well as *Garnoderma* (tree mushrooms) have been documented. The *Pleurotus species* which are currently grown in Tanzania are such as *Pleurotus flabellatus*, *Pleurotus florida*, *Pleurotus specie HK37*, *Pleurotus ostreatus*, *Pleurotus sajor-caju*, Pleurotus specie WC537 and *Pleurotus* specie WC814 (Kivaisi, 2007).

2.5 Nutritional Composition of Mushroom

Since ancient times, mushrooms have been appreciated as a very vital food and at present, the utilization of mushrooms has increased abruptly due to their nutritional and health-giving properties (Moon & Lo, 2014).

2.5.1 Protein Content

Dunkwal and Jood (2009) documented that the mushroom protein is of high-quality value since it constitutes all amino acids which cannot be synthesized in the human body (essential amino acids). The effective utilization of mushrooms may help to reduce the protein-energy malnutrition to young children in developing countries in places where animal-source protein is scarce or unaccepted by religious beliefs.

Van-Griendsven (2000) stated that mushrooms are rich in highly digestible protein as compared to other vegetable foods though it differs from one specie to another, normally it ranges between 14 - 44%. According to Kim *et al*. (2009), edible mushrooms contain amino acids with an average total of 120.79 mg/100 g. Patil *et al*. (2010) identified 15 bound amino acids in mushrooms which are cysteine (1.74 mg/100 g fresh weight), histidine (2.25 mg), leucine (5 mg), lysine, aspartic acid, serine, glycine, glutamic acid, alanine, hydroxyl proline, methionine, proline, phenylalanine, valine, and isoleucine.

A report by Kelemen *et al*. (2005) stated that *Agaricus bisporus* hold the amount of protein in the range 22.7 to 40.8 g/100 g of dry weight while the total amino acids ranges between 32 - 43%. Mushrooms constitute a considerable amount of glutamic acid, arginine, and aspartic acid but methionine and cysteine are present in a limited amount.

2.5.2 Mineral Content

According to Gençcelep *et al*. (2009), dried mushrooms hold 0.17 - 8.80 mg/100 g of calcium, 9.23 - 107 mg/100 g of copper, 12.6 - 29.1 mg/100 g of potassium, 0.64 - 4.49 mg/100 g of phosphorus, 0.03 - 4.85 mg/100 g of sodium, and 26.7 - 185 mg/100 g of zinc. A study by Chang and Miles (1989) documented mushrooms as an important source of minerals as the ash content observed in *Agaricus bisporus, Volvariella volvacea*, *Lentinus edodes* and *Pleurotus species* range between 8 - 10%, 11 - 15%, 7% and 5 - 15%, respectively. Potassium is plentiful in mushrooms since it comprises approximately 45% of total ash content, while calcium, sodium, phosphorus, and magnesium covers 56 - 70%.

2.5.3 Vitamins

Mushroom has been observed to be a tremendous source of B group vitamins such as riboflavin, niacin, pantothenic acid, thiamine, biotin, folate and vitamin B12. Oyster mushroom holds 4.8 mg of thiamine, 4.7 mg of riboflavin and 108.7 mg niacin (Ranote *et al*., 2007). The ascorbic acid content of *Pleurotus florida* and *Pleurotus Sajor caju* was found to be 5.4% and 5.1% respectively of fresh weight basis. Oyster mushroom has the ability to produce vitamin D when exposed to UV light hence they are the chief source of vitamin D in edible form (Randhawa & Ranote, 2004).

2.5.4 Carbohydrate Content

According to Loria-Kohen *et al*. (2014), carbohydrates comprise the large portion of mushrooms as they range between 35% to 70%. For instance, carbohydrates in *Agaricus bisporus* ranges between 43.3 g and 61.3 g per 100 g of dry weight. The mushroom carbohydrates are mainly the structural carbohydrates of cell walls which are non-digestible by human enzymes upon consumption. The carbohydrates present in the mushroom are in form of polysaccharides (glucans, chitin, pectin, glycogen and hemicelluloses), monosaccharides (glucose, mannose, ribose and fructose), disaccharides (sucrose and trehalose) sugar alcohols (inositol and mannitol) and sugar acids (glucoronic acid and galacturonic acid) as a substitute for starch. Kim *et al*. (2009) documented that mushroom species have xylose (16.83%), glucose (34.70%) and mannose (36.23%), as the major components of carbohydrate.

2.5.6 Calories

According to Kaur (2016) mushrooms are graded between low-grade meats and high-grade vegetables as they give about 35 calories/100 g. Adejumo and Awosanya (2005) stated the energy value of mushroom tend to differ from one specie to another but are almost equivalent to the energy value of an apple. Dried oyster mushroom is reported to have 412 kcal/100 g (Dunkwal & Jood, 2009).

2.5.7 Fiber Content

A study by Loria-Kohen *et al*. (2014) declared that mushrooms contain considerable amounts of fibers as they range from 5.5 to 42.6% of dry weight in *Pleurotus eryngii*, *Pleurotus ostreatus*, *Agaricus bisporus*, *Boletus group*, and *Agrocybe aegerita*. Higher quantities of insoluble dietary fibers (2.28 - 8.99 g/100 g) fresh weight are found in mushrooms as compared to soluble fibers (0.32 – 2.20g/100 g). Kakon *et al*. (2012) reported that 100 g of dried mushroom contains 26 g of fiber.

2.5.8 Fat Content

According to Kumari and Murthy (2000) mushroom is comprised of very low-fat content since it holds about 1.1% - 8.3% fat on a dry weight basis. All lipid classes such as free fatty acids, sterols, glycerides and phospholipids are present in mushroom and 72 % of total fatty acids is clearly declared to be unsaturated accredited by the presence of linoleic acid constituting about 60% in *Agaricus bisporus*, 70 % in *Volvariella volvacea* and 76 % in *Lentinus edodes* (Ranote *et al*., 2007). Generally, mushroom contains a high amount of unsaturated fatty acid particularly palmitic acid (C18:2) and oleic acid (C18:1) as compared to saturated fatty acids (Loria-Kohen *et al*., 2014).

2.6 Processing of Mushrooms to Flour

Since mushrooms are highly perishable, their processing is very crucial to promote shelf life. The processing of raw mushrooms to mushroom flour involves different drying techniques and treatment so as to come up with the high quality and nutritious mushroom flour. But in the drying process of the mushrooms, most of the nutrients are lost due to several factors but mostly due to the application of high temperature. According to Giri and Prasad (2013), drying is among the best way of preserving mushroom as it reduces mushroom perishability while the dried mushroom being a crucial ingredient in the formulation of snacks, sauces, pizzas, instant soups, methods of mushrooms, among others are such as fluidized bed drying, freeze-drying, hot air cabinet drier, vacuum drying, osmotic dehydration, conventional hot air drying, microwave drying, solar drying, open sun drying and electric oven drying but mostly solar, electric oven and open sun drying methods are used due to their easy affordability (Tolera & Abera, 2017).

Furthermore, Tolera and Abera (2017) revealed that drying of mushrooms using sun, solar and oven drying methods has a tendency of reducing the nutritional content of oyster mushrooms. The proximate composition of the fresh mushroom decreased from 28.85 - 25.91% (crude protein), 2.47 to 2.18% (crude fat), 12.87 to 10.41% (crude fiber) and 48.16 to 42.14% (carbohydrate). However, the ash content seemed to be altered by the drying process as it increased from 9.76 to 10.91%.

Among the three drying techniques, oven drying method was the best in terms of retaining high quantities of ash content (11.06%) and carbohydrates content (43.64%) but it scored the least in the retention of crude protein content (24.99%) due to occurrence of protein denaturation in the presence of high temperature. Sun-drying method was reported to retain high moisture (9.58%) which may be caused by being absorbed by the dried samples from the environment, but also due to the formation of case hardening which limit the easy evaporation of moisture from the sample while solar drying method was the best in removing the moisture content in mushroom samples as it had the lowest value of 7.77% (Tolera & Abera, 2017).

Sun-drying method was reported to be the best method in retaining the protein content in mushroom samples due to the application of low temperature and the sun-dried mushroom samples had high protein value of 27.14% as compared to oven and solar drying methods. Oven drying method scored the least in retaining protein content as it had the lowest value of 24.99% due to the use of high temperature (60 °C) during the drying process, which caused the denaturation of protein and the acceleration of continuous browning reaction which lead to loss of protein (Tolera & Abera, 2017). Hassan and Medany (2014) revealed that the drying process of mushrooms results in a considerable reduction of their protein contents. But also the texture of oyster mushrooms has been reported to be affected by the drying process (Kotwaliwale *et al*., 2007).

No significant ($p \geq 0.05$) difference in retaining the fat content was observed between the sun (2.21%) and solar (2.22%) drying methods. However, the oven drying method was documented to affect the fat content in dried mushroom samples due to the application of high temperature and it had the lowest value of 2.12% only. Solar drying method outweighed other drying methods (sun and oven) as it had the highest value of crude fiber content (10.90%) in comparison to the sun (10.14%) and oven (10.21%) drying methods. Oven drying method was the best in retaining the ash content in dried mushroom samples as it had the highest value of (11.06%) as compared to sun (10.93%) and solar (10.74%) drying methods. Oven drying method was observed to be the best in the retention of carbohydrates contents in dried mushroom samples with the highest value of 43.64% while the lowest value was obtained in open sun-dried mushroom (39.99%) (Tolera & Abera, 2017). Generally, it was concluded that solar and oven drying methods are the best in protecting the mushroom samples from dust, rain and insects but also it provided the high quality dried mushrooms as compared to the sun drying method.

2.7 Value Addition of Mushroom

The consumer's desire for diverse products has inspired the innovation of readymade products from mushrooms or the mushroom value-added processed foods (Kumar & Barmanray, 2007). According to Ranote *et al*. (2007) mushrooms are used to substitute traditional bites like cheese sandwiches, patties, biriyani, poached eggs, stuffed dosa, fritters and omelets. *Pleurotus* mushrooms were used in the preparation of soup powders, chutney, pickles, biscuits, sev and papad which are widely accepted in Indian palate (Tyagi & Nath, 2005).

Mushrooms are added in salads, sandwiches and soups but also they act as an appetizer to many vegetables like casseroles and stews. Standardized *Pleurotus* mathri is a novel mushroom value-added product made from a mixture of 10 g of *Pleurotus* powder, 90 g of wheat flour, 2 g of salt, 0.5 g of baking powder, 35 mL of water and 200 g of hydrogenated vegetable oil (Kumar *et al*., 2006). The dried mushroom powders produced from *Pleurotus species* and *Agaricus bisporus* are incorporated in several convectional recipes to alter their nutritional value but also they are included in maize, millet and wheat flours to produce bread and rotis (Mane *et al*., 2000).

Composite flours are referred to as the blends of flours from rich starchy tubers such as sweet potatoes, yams, cassava and flours rich in protein like mushroom flour, soy flour and/or cereals flours like millet, buckwheat, maize, rice, sorghum and barley flours combined with wheat flour or without wheat flour. According to Shittu *et al*. (2014) composite flour has been widely used as supplements to enhance the nutritive value of food in various parts of the world.

2.8 Nutritional Composition of Composite Flours

Many researchers have done various studies concerning the composite flours of cereals and mushroom flours. Ekunseitan *et al*. (2017) produced a composite flour by blending 11 different proportions of wheat flour, High-Quality Cassava Flour (HQCF) and mushroom flour with 100% wheat flour as control and studied their nutritional composition, functional and pasting properties. The study revealed that the addition of mushroom flour enhanced the nutritive value of the supplemented flours in terms of protein, minerals, vitamins and fiber contents. Bello *et al*. (2017) replaced wheat flour with 0%, 5%, 10% 20% and 30% of mushroom flours for the development of nutritious biscuits. The study revealed that there was a significant difference ($p \leq 0.05$) in protein (13.04 - 15.55%), ash (1.52 - 3.85%) and crude fiber (2.10 - 2.93%) between the 100% wheat flour and the formulated wheat-mushroom composite flours.

Okafor *et al*. (2012) documented the formulation of wheat-mushroom composite flours for whole bread making and studied the proximate components and rheological properties of the bread. It was evidenced that there was a significant difference ($p \leq 0.05$) between the whole wheat flour and the formulated wheat-mushroom composite flour whereby protein content was improved from 10.21 to 23.92%, fat (1.72 to 1.92%), crude fiber (1.59 to 2.57%), ash (0.88 to 2.69%) and energy (275.4 to 276.45 kcal). After substituting the cassava starch with 10%, 20%, 30% and 40% of mushroom (*Pleurotus pulmonaris*) inclusion, Ojo *et al*. (2017) evidenced the alteration of the nutritive value of cassava starch as the protein content increased from 0.55 to 26.23%, fat (0.34 to 2.01%) and ash (0.32 to 8.24%). According to Sulieman *et al*. (2017), greater improvement was observed in nutritional composition, functional properties as well as syneresis properties of sweet potato and glutinous rice composite flours upon the addition of various levels of button mushroom powder. It was observed that ash content increased from 1.23 to 2.34 g/100 g, protein (5.24 to 11.74 g/100 g), fat (0.15 to 0.93 g/100 g, total dietary fibers (3.97 to 8.61 g/100 g) and energy (345.71 to 350.77 kcal/100 g).

Generally, complementary foods developed from locally available, affordable indigenous foodstuffs have been previously recommended as appropriate for resource-limited settings (Mithamo *et al*., 2020). Oyster mushroom on the other hand provides numerous macro and micronutrients. Bamidele and Fasogbon (2020) reported that the laboratory analysis of oyster (*Pleurotus ostreatus*) grown on hardwood sawdust indicated 26.67% protein content of dry weight matter. In the similar study, authors reported the level micronutrient of the oyster mushrooms incorporated into the flour (mg/100 g) to be as high as 3.51, 3.51, 22.81, 10.36, 1.25, and 0.96 for Ca, Na, K, P, Mg and Zn, respectively (Bamidele & Fasogbon, 2020). These results highlight the potential of oyster mushroom composite flour in curbing the two major forms of malnutrition, the protein-energy malnutrition and micronutrient deficiency (Mithamo *et al*., 2020).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Sample Collection and Preparation

White maize grains were purchased from the central-local market in Morogoro, Tanzania. Fresh oyster mushrooms were purchased from Okoa Oyster Mushroom Supplies and Enterprises in Morogoro, Tanzania. Collected materials (white maize grain and fresh oyster mushrooms) were immediately packed in airtight polyethylene plastic bags and transported to the Food Science laboratory.

3.1.1 Preparation of Maize Flour

White maize grains were sorted to remove extraneous materials, winnowed, dehulled and washed thoroughly with potable water to ensure complete removal of dust and unwanted materials. Thereafter, the clean maize grains were sun dried to moisture content below 10%. The dried maize grains were milled using a hammer mill (VWR, United Kingdom) and sieved using a 1mm sieve to obtain fine maize flour.

3.1.2 Drying of Fresh Oyster Mushroom

Fresh oyster mushrooms were sorted, washed thoroughly with potable water, sliced and divided into three groups for drying. The first group of cleaned fresh oyster mushroom samples were dried using open sun drying method for 36 hours at a temperature range of 28 – 30 °C. The second group of sample was dried by direct solar for 12 hours at a temperature range of 55 – 60 °C. The third group cleaned sample was dried using an electric oven at a temperature of 45°C for 24 hours. All drying methods were intended to dry the fresh oyster mushroom to moisture content below 10%.

3.1.3 Preparation of Oyster Mushroom Flour

The dried oyster mushroom obtained from the three drying methods were milled using a heavy-duty blender (Kenwood, BY-J-823, China) and sieved using a 1mm sieve to obtain fine oyster mushroom flour.

3.1.4 Preparation of Maize - Mushroom Composite Flour

Maize and mushroom flours were then blended at different ratios as follows: the first flour sample had a ratio of 100% maize flour and 0% of oyster mushroom flour (100:0) which was used as a control. The second maize-mushroom composite flour sample had a ratio of 70% maize flour and 30% oyster mushroom flour (70:30). The third maize-mushroom composite flour sample had a ratio of 60% maize flour and 40% oyster mushroom flour (60:40). The fourth maize-mushroom composite flour sample had a ratio of 50% maize flour and 50% oyster mushroom flour (50:50). Selection of formulation ratios/ blends was based on obtaining the best ratio rich in nutrients, and that will not cause negative impact to sensory qualities of the porridge made of maize-mushroom composite flour. Reference was made from previous similar studies reported formulations of oyster mushroom with other cereal based foods (Ishara *et al*., 2018; Bamidele & Fasogbon, 2020).

3.1.5 Preparation of Maize-mushroom Composite Porridge

Three samples of porridges were prepared from three groups of the formulated maize-mushroom composite flours (70:30, 60:40, and 50:50 maize: mushroom flour w/w). A porridge sample from white maize flour (100:0 maize: mushroom flour w/w) was prepared as a control. Porridge samples were prepared by mixing 350 g of flour in 1500 mL of portable boiling water. The mixture was left to boil on a gas cooker for 15 minutes with continuous stirring. Each sample of porridge was sweetened by the addition of 30 g of brown sugar.

3.2 Determination of Proximate Composition

Determination of proximate composition (moisture, ash, crude protein, crude fat and crude fiber) of maize flour, oyster mushroom flour and the blended maize-mushroom composite flour was performed using standard official analytical methods AOAC (2003).

3.2.1 Analysis of Crude Protein

The Kjeldahl method AOAC (2003) was used to analyze crude protein content in each sample, according to Chang and Zhang (2017). Firstly, a mixture of K_2SO_4 (10g), $CuSO_4$ (1 g), and selenium powder (0.1 g) were prepared and used as a Kjeltec catalyst. Afterwards, 10 ml of concentrated H_2SO_4 and Kjeltec catalyst were added in 1g of each sample for digestion. The mixture was heated at 420 °C for 2 hours to allow the digestion of the sample. About 10 mL of

0.5 NaOH was added in 10 mL of digested samples to provide a basic condition. Following the reaction, NH_3 was collected as NH_4OH in a conical flask containing 20 mL of 4% boric acid and a drop of modified methyl red as an indicator. Thereafter, the distillate was titrated against 0.1 N HCl solution until the endpoint was obtained. The percentage nitrogen in the sample was determined using the expression below:

$$\% \text{ Nitrogen} = (V_1 - V_2) \times N \times f \times 0.014 \times \frac{100}{V} \times \frac{100}{S} \quad (1)$$

where V_1 = titer for the sample (mL), V_2 = titer for blank (mL), V= volume of diluted digest taken for distillation (10 mL), N= Normality of HCl solution, f = factor for standard HCl solution, 0.014 = milliequivalent weight of Nitrogen, S= weight of the sample taken (g).

The amount of crude protein in the sample was determined by multiplying the percentage nitrogen with 6.25 as a protein conversion factor using the expression below:

$$\% \text{ Protein} = \% \text{ Nitrogen} \times \text{Protein factor} \quad (2)$$

3.2.2 Analysis of Crude Fat

The determination of crude fat in the sample was performed using standard procedure AOAC (2003) with petroleum ether as an extracting solvent, as described by Nielsen and Carpenter (2017). Extraction of fat was done by placing 5 g of each sample of maize flour, oyster mushroom flour, and the blended maize-mushroom blended flours in the extraction thimble of Soxhlet apparatus (FOSS – Soxtec 2055, Denmark), followed by immersing the thimble inside the extraction can containing 55 mL of petroleum ether. The extraction thimble with a fat-containing sample was heated to 60 °C for 6 hours. Thereafter, solvent removal was done with a vacuum rotary evaporator's aid at 40 °C, while fat drying was done in the dry oven at 70 °C for 30 minutes. The amount of crude fat was obtained by subtracting an empty flask from the weight of the flask containing dried fat. The percentage of crude fat was obtained using the expression below:

$$\% \text{ Fat} = \left(W_1 - \frac{W_2}{W_1}\right) \times 100 \quad (3)$$

where W_1= weight of the sample before extraction, W_2 = weight of the sample after extraction

3.2.3 Analysis of Crude Fiber

The amount of crude fiber in each sample was determined using standard procedures of AOAC (2003) described by Nielsen (2010). About 2 g of each sample was added to a mixture of 200 mL of 1.25% H_2SO_4 and 0.31 N NaOH, boiled for 30 minutes, and washed with ethanol and petroleum ether twice. The residues obtained were then placed in clean, dry weighed crucibles and dried overnight at 100 °C inside the moisture extraction oven. Thereafter, the crucibles were heated in a muffle furnace at 600 °C for 6 hours, cooled in a desiccator, and weighed again. The weight differences of the crucibles were noted as crude fiber and calculated as percentage crude fiber as expressed below:

$$\%\ \text{Fiber} = W_1 - \frac{W_2}{W_3} \times 100 \tag{4}$$

where W_1 = weight of the sample before heating, W_2 = weight of the sample after heating, W_3 = weight of the original sample.

3.2.4 Determination of Ash Content

The ash content in each sample was determined using the AOAC (2003) standard procedures described by Harris and Marshall (2017). The Carbolite muffle furnace was used to heat the clean empty crucibles at 600 °C for 1 hour. The empty crucibles were weighed after cooling in a desiccator. The sample (2 g of each) was then placed in the crucibles, and their weight recorded, followed by burning in the muffle furnace at 550 °C for 6 hours. The burnt crucibles containing samples were cooled in the desiccator and weighed again. The percentage of ash content was determined by using the following expression:

$$\%\ \text{Ash} = (W_3 - W_1) \times \frac{100}{W_2} \tag{5}$$

where W_1= weight of empty crucible, W_2= weight of the sample, W_3 = weight of the heated sample, and the crucible.

3.2.5 Determination of Moisture Content

Determination of moisture content in each sample was performed using the AOAC (2003) standard procedures described by Bradley (2010). About 2 g of each sample was weighed into a dried moisture dish and placed in the moisture extraction oven (Wagtech, Germany) at 105 °C for 5 hours. Thereafter, the dried samples were cooled in a desiccator and weighed again.

This process was repeated thoroughly until the constant weight was attained. The percentage of moisture content of samples was calculated using the following expression:

$$\% \text{ MC} = \left(\frac{W_1 - W_2}{W_1}\right) \times 100 \quad (6)$$

where W_1= weight of the fresh sample (g), W_2= weight of the dry sample (g)

The percentage of moisture content (% MC) was used to obtain the dry matter content of the sample using equation (7) below:

$$\% \text{ Dry matter} = 100 - \% \text{ MC} \quad (7)$$

3.2.6 Analysis of Carbohydrate Content

The content of carbohydrate in each sample was determined by the method described by Nielsen (2010). The percentage of carbohydrate was obtained by subtracting 100 from the summation of crude protein, crude fat, crude fiber, ash, and moisture content.

% Total Carbohydrate = 100 - % (Protein + Fat + Fiber + Ash + Moisture content (8)

3.2.7 Determination of Energy Value

The energy value was determined using the method described by Farzana and Mohajan (2015). For each blended flour sample, the energy value was obtained as the summation of crude protein, crude fat, and carbohydrate and their respective physiological values (Atwater's conversion factors) of 4, 9, and 4 calories.

3.3 Determination of Mineral Content

The mineral (iron, zinc, calcium, and potassium) contents of control maize flour and complementary flour blends were determined using Atomic Absorption Spectrophotometer, AAS (Thermo Scientific® iCE 3500, Waltham, USA). The AOAC (2003) standard procedures were followed as described by Yeung *et al*. (2017). The wavelength used in reading the absorbance of cations in the AAS were 248.3 nm for Iron (Fe), 213.9 nm for Zinc (Zn), and 422.7 nm for calcium. Potassium was determined using an Air-Liquefied Petroleum Gas flame on a Flame photometer. The calculation of mineral content (mg/100 g) in the sample was done as shown below:

$$\text{Mineral content } \left(\frac{\text{mg}}{100\text{g}}\right) = \text{R} \times 100\text{mL} \times \text{D.F} \left(\frac{\text{R}\times 100\text{mL}\times \text{D.F}}{\text{S}\times 1000}\right) \times 100 \quad (9)$$

where R= absorbance reading in ppm, 100 = volume of sample made, D. F= dilution factor, 1000 = conversion factor to mg/100 g, S= sample weight.

3.4 Sensory Evaluation

A total of 20 semi-trained panel members comprised of nursing mothers and caregivers from Nambala Catholic Mission Dispensary in Arusha, Tanzania, were instructed to use the five-point hedonic scale for sensory evaluation of porridge. The coded maize flour porridge's sensory attributes as control and porridge from three complementary flour blend samples were evaluated using a five-point hedonic scale. The scale was in the range of 1 = 'dislike very much' and 5 = 'like very much' for the characteristics of colour, flavour, aroma, texture, and general acceptability.

3.5 Statistical Analysis

Experiments were conducted using a completely randomized design, and statistical analysis of data performed using Statistical Package for Social Sciences (SPSS version 20). Data were further subjected to one-way analysis of variance (ANOVA), the main treatment means calculated from the triplicate sample analyses ($n \geq 3$) were compared using the Least Significant Difference (LSD) test ($p \leq 0.05$). All results are presented as the means ± standard deviation (SD) of multiple independent determinations.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Proximate Composition of Fresh and Dried Oyster Mushroom

The results of proximate analysis of fresh oyster mushroom and the oyster mushroom dried by three different drying methods (oven, sun and solar) are shown in Table 2. Significant differences ($p \leq 0.05$) in proximate composition of oyster mushroom was observed among fresh samples and those dried by either oven, sun and solar drying methods. The moisture content of the fresh oyster mushroom was observed to be 91.44%. The study results were higher than those reported by Khan *et al*. (2008) who found the fresh oyster mushroom to have 86.5% moisture content. The moisture content values of fresh oyster mushroom reported in the current study were higher than those reported by Hassan and Medany (2014). On the contrary, Michael *et al*. (2011) and Alam *et al*. (2008) reported comparatively lower values of moisture content of 85.55% and 86% respectively, for fresh oyster mushrooms. The difference in moisture content of fresh oyster mushroom could be attributed to difference in geographical location and conditions where the mushrooms were grown and the analytical methods.

Higher moisture content (9.46%) was observed in the sun-dried mushroom samples while the lower value (9.06%) was observed in the oven-dried mushroom sample (Table 2). Lower moisture content in the latter could be attributed to moisture absorption from the surrounding environment during sun-drying. On the other hand, lower moisture content observed in oven-dried mushroom samples could be due to a constant and controlled supply of heat in the oven. Overall, the moisture content values of dried mushroom samples are lower compared to those reported by Tolera and Abera (2017) who reported 9.58% in sun-dried mushroom samples pre-treated in salt concentration before drying, and 7.7% in solar-dried mushroom. These results highlight that both sun, solar and oven drying methods could be suitable methods for drying oyster mushroom.

Table 2: Proximate Composition of Fresh and Dried Oyster Mushroom (%)

Treatment	MC	Ash	Fiber	Fat	Protein	CHO	Energy (Kcal)
Fresh	$91.44^{c}\pm0.60$	$8.83^{a}\pm0.04$	$22.95^{a}\pm0.01$	$0.59^{a}\pm0.002$	$60.70^{d}\pm0.01$	$6.93^{d}\pm0.02$	$290.61^{b}\pm0.02$
Oven-dried	$9.06^{a}\pm0.02$	$9.01^{a}\pm0.01$	$22.45^{a}\pm0.01$	$0.35^{a}\pm0.03$	$33.58^{a}\pm0.71$	$25.71^{a}\pm0.54$	$245.96^{a}\pm0.41$
Sun-dried	$9.46^{b}\pm0.01$	$8.82^{a}\pm0.02$	$22.05^{a}\pm0.03$	$0.37^{a}\pm0.04$	$34.92^{b}\pm0.07$	$24.36^{b}\pm0.01$	$246.63^{a}\pm0.17$
Solar-dried	$9.45^{b}\pm0.03$	$8.81^{a}\pm0.03$	$22.41^{a}\pm0.01$	$0.38^{a}\pm0.03$	$36.42^{c}\pm0.50$	$22.51^{c}\pm0.64$	$246.0^{a}\pm0.50$

Mean ±SD (n=3) on a dry weight basis, MC: Moisture content, CHO: carbohydrates. Means in the same column with different letters as superscript are significantly different ($p\leq0.05$)

Significant differences ($p \leq 0.05$) were observed in protein content of fresh oyster mushroom and mushroom samples dried by oven, sun or solar drying method. Mushrooms have been reported to contain a high-quality protein with all essential amino acids (Dunkwal *et al*., 2007). The current results have shown high percentage of protein (60.7%) in fresh oyster mushroom samples (Table 2). These finding are higher than those reported by Khan *et al*. (2010) who reported the protein content of the fresh oyster mushroom ranged between 17% and 42%. Similarly, Michael *et al*. (2011) reported 30.9% of protein content of the fresh mushroom whereas Hassan and Medany (2014) observed as low as 28.8% of protein content. Again, the difference in the content of protein for oyster mushroom reported by various authors could be attributed partly to the difference in geographical location and conditions where the mushrooms were grown and also to the analytical methods employed.

The protein values of the mushroom samples dried by an oven, sun and solar drying methods were significantly ($p \leq 0.05$) different from each other as shown in Table 2. Significantly higher protein content (36.42%) was observed from the mushroom samples dried in the solar when compared to those of oven and sun-drying treatments. Lower protein content (33.58%) was observed in the oven-dried mushroom samples. It was found that though a medium temperature of 45 °C was used in the oven drying method, it affected the protein content since the samples were exposed to heat for a long time as compared to other drying methods. This led to denaturation of protein hence its reduction in dried mushroom samples. Also, the reduction of protein in dried mushroom samples may be due to browning reactions which were facilitated by the presence of heat (Hassan & Medany, 2014). Generally, the drying process causes a considerable decrement in protein content. However, this study results were higher than those reported by Tiram (2013) who observed the protein content to be 20.89 % in the sun-dried mushroom samples and 23.84% in the oven-dried mushroom samples.

With respect to crude fat, no significant differences ($p \geq 0.05$) were observed between fat content of fresh oyster mushroom and that of dried samples for both drying methods. The crude fat content of the fresh oyster mushroom was 0.59% (Table 2). Naturally, oyster mushroom contains low amount of fat yet very important when consumed. The findings obtained in present study are lower than those reported by Tolera and Abera (2017) who reported 2.4% fat content in fresh oyster mushroom. On the other hand, Alam *et al*. (2008) and Michael *et al*. (2011) reported two- and three-fold higher fat content in oyster mushroom, respectively than those reported in the present study.

The values of crude fat content were 0.35%, 0.37% and 0.38% for oven, sun and solar-dried mushroom samples, respectively (Table 2). No significant differences ($p \geq 0.05$) in crude fat content were observed between the studied drying methods. Comparatively higher values (1.33% and 1.69) of fat content were reported by Tiram (2013) in sun and solar-dried mushroom, respectively. The present study results were also lower than those reported by Reguła and Siwulski (2007), who stated the crude fat content of dried oyster mushroom to be 2.66%. Similar trend was also reported by Tolera and Abera (2017) observed the fat content to be 2.12%, 2.22% and 2.21% for the oven-dried, sun-dried and solar-dried mushroom samples, respectively.

Mushrooms are excellent sources of dietary fibers as they contain non-starch polysaccharides. In the current study, no significant differences ($p \geq 0.05$) in crude fiber content were observed between the fresh oyster mushroom and the mushroom samples dried by sun, solar or oven drying methods. The present study results revealed that the crude fiber content in fresh oyster mushroom was 22.95%. These results were two-fold higher than those reported by Michael *et al*. (2011), and those reported by Tolera and Abera (2017). On the contrary, the values of crude fiber obtained in the present study were in the range of those reported by Khan *et al*. (2008) who found 26.2% in fresh oyster mushrooms.

On the other hand, no significant differences ($p \geq 0.05$) were observed between crude fiber contents of the oven, sun and solar-dried mushroom samples (Table 2). The oyster mushroom sample had 22.45%, 22.41% and 22.05% crude fiber content for in oven, solar and sun-dried samples, respectively. The results are two-fold higher than those reported by Dunkwal *et al*. (2007) who found the crude fiber content of the sun-dried and oven-dried mushroom to contain 12.59% and 12.58%, respectively. These results highlights that both drying methods studied in the present study could be suitable in retention of crude fibre nutrients.

The ash content of the fresh oyster mushroom was observed to be 8.83%, where as those of dried samples were 8.82%, 8.81% and 9.01%, for sun, solar- and oven dried, respectively (Table 2). No significant differences ($p \geq 0.05$) in ash content were observed between the fresh oyster mushroom and dried samples for both drying methods. The present results corroborate with those reported by Tolera and Abera (2017) and Khan *et al*. (2008) who observed that ash content in fresh oyster mushroom to be 9.76% and 7.4%, respectively. Furthermore, this study results are in close agreement to those reported by Tiram (2013) who observed the ash content of dried oyster mushroom to be 8.40%. On the other hand, Ahmed *et al*. (2016) observed 11.4%

ash content in dried mushroom which is slightly higher than the values reported in the present study. Okafor *et al*. (2012) and Li *et al*. (2017) observed dried oyster mushroom had 7.6% and 7.9% ash contents, slightly lower than the present reported results.

Significant differences ($p \leq 0.05$) were observed in carbohydrate content of fresh oyster mushroom and the mushroom samples dried by oven, sun and solar drying methods. The carbohydrate content of fresh oyster mushroom was found to be 19.93 % as shown in Table 2. The obtained results of this study are lower than those reported by Alam *et al*. (2008) who observed fresh oyster mushroom contain 37.8 g/100 g carbohydrate content. Moreover, significance difference ($p \leq 0.05$) in carbohydrate content was observed in mushroom samples dried by oven, sun and solar drying methods (Table 2). The highest value (25.71%) of carbohydrate content was recorded for the oven-dried mushroom samples, whereas the lowest value (22.51%) was observed in the solar-dried mushroom samples. This study results are lower than those reported by Tiram (2013) who found the sun-dried mushroom sample to contain 60.34% of carbohydrate content while oven-dried mushroom samples contained 57.41% carbohydrate. Ahmed *et al*. (2016) and Gwirtz and Garcia-Casal (2014) found higher carbohydrate content in dried mushroom as compared to study findings as they observed 29.60% and 76.9% carbohydrate content respectively.

Furthermore, significant differences ($p \leq 0.05$) were observed in energy value of fresh oyster mushroom and the mushroom samples dried by oven, sun and solar drying methods. The energy value of fresh oyster mushroom was found to be 290.61 Kcal as shown in Table 2. The energy value was obtained to be 245.96 Kcal for oven-dried mushroom, 246.63 Kcal for sun-dried and 246.0 Kcal for solar-dried mushroom samples (Table 2). The results are lower than those reported by Reguła and Siwulski (2007) who observed 345 Kcal/100 g in oyster mushroom. Moreover, this study finding are slightly higher as compared to those stated by Dundar *et al*. (2008) and lower than those reported by Okafor *et al*. (2012) as they observed the oyster mushrooms have 243 kcal/100 g and 313 kcal/100 g respectively.

From the above reported results (Table 2), it can be concluded that both sun, solar and oven drying methods have shown potential to retain the significant amount of proximate composition of both fresh and dried oyster mushrooms. However, the solar drying method outweighed the other two drying methods (oven and sun-drying) as it was observed to retain a reasonable amount of nutrients while protecting the samples from physical contaminating agents such as insects, dust, sand, stones and grasses.

4.2 Mineral Composition of Fresh Oyster Mushroom and Dried Oyster Mushroom

The results of the minerals composition of fresh oyster mushroom and oyster mushroom samples dried by different drying methods such as oven, sun, and solar drying are shown in Table 3. It was observed that there were no significant ($p \geq 0.05$) differences in mineral composition between the fresh oyster mushroom and the oyster mushroom samples dried by either oven, sun and solar drying methods.

Table 3: Mineral Composition of Fresh and Dried Oyster Mushroom (mg/100 g)

Treatment	Fe	Zn	Ca	K
Fresh	$12.85^{a}\pm0.02$	$8.75^{b}\pm0.04$	$51.87^{b}\pm0.05$	$2499.27^{a}\pm0.29$
Oven-dried	$12.58^{a}\pm0.02$	$8.46^{b}\pm0.19$	$51.49^{b}\pm0.31$	$2490.01^{a}\pm0.22$
Sun-dried	$12.55^{a}\pm0.05$	$8.23^{b}\pm0.01$	$51.43^{b}\pm0.02$	$2488.44^{a}\pm0.55$
Solar-dried	$12.57^{a}\pm0.12$	$8.31^{b}\pm0.25$	$51.45^{b}\pm0.31$	$2489.30^{a}\pm0.22$

Mean ±SD (n=3) on a dry weight basis, Fe: iron, Zn: zinc, Ca: calcium, K: potassium, means in the same row with different letters as superscript are significantly different ($p \leq 0.05$)

Iron content in fresh oyster mushroom was observed to be 12.85 mg/100 g. This study results are lower than those reported by Khan *et al*. (2008) who observed the values of iron content in fresh oyster mushroom to range between 55 mg/100 g - 65 mg/100 g. Furthermore, Alam *et al*. (2008) reported mushrooms to have 55.45 mg/100 g which is much higher than the results of this study findings while Michael *et al*. (2011) reported mushrooms to have 4.94 mg/100 g iron content which is far lower than this study finding.

Furthermore, the iron content of oven-dried, sun-dried and solar dried mushroom samples were observed to have 12.58 mg/100 g, 12.55 mg/100 g and 12.57 mg/100 g iron content, respectively. These results are higher than those reported by Roy *et al*. (2015) and Mallikarjuna *et al*. (2012) who found the values of iron in dried mushroom to be 5.2 mg/100 g and 6.27 mg/100 g respectively. Li *et al*. (2017) and Reguła and Siwulski (2007) found dried mushrooms have 7.1 mg/100 g and 6.86 mg/100 g values of iron content which are also lower than the study findings.

The zinc content of the fresh oyster mushroom was found to be 8.75 mg/100 g. Similar results were reported by Khan *et al*. (2008) who found the zinc content in fresh mushrooms to range from 3 mg/100 g to 27 mg/100 g. Michael *et al*. (2011) stated that fresh mushrooms have 3.3 mg/100 g zinc content which is lower than the study findings while Alam *et al*. (2008) observed 26.565 mg/100 g of zinc content in fresh mushroom which is higher than the study findings.

However, the zinc content of the mushroom samples dried by the oven, sun and solar drying methods were 8.46 mg/100 g, 8.23 mg/100 g and 8.31 mg/100 g respectively (Table 3). The results are higher than those reported by Roy *et al*. (2015) who found the value of zinc to be 2.5 mg/100 g. Gençcelep *et al*. (2009) stated the values of zinc content in dried mushrooms range between 26.7-185 mg/100 g which are higher than the study results. Li *et al*. (2017) showed the amount of zinc content in dried mushroom range between 4.2 mg/100 g - 5.5 mg/100 g while Mallikarjuna *et al*. (2012) observed dried mushroom have 5.06 mg/100 g zinc content.

The calcium content of fresh oyster mushroom was reported to be 51.87 mg/100 g. This study result is higher as compared to the results reported by Çağlarırmak (2007) who observed the calcium content to range between 2 mg/100 g - 36 mg/100 g. Alam *et al*. (2008) also reported mushroom contains 35.9 mg/100 g zinc content which is also lower than the study findings. However, higher calcium content (51.49 mg/100 g) was observed from the mushroom samples dried in the oven when compared to those dried by the sun (51.43 mg/100 g) and solar (51.45 mg/100 g) drying methods. The results are higher than those reported by Roy *et al*. (2015) who found the calcium content to be 5.9 mg/100 g. Calcium value in dried mushrooms was high than the study findings observed by Çağlarırmak (2007) who observed calcium content in dried mushroom range between 0.17 mg/100 g - 8.80 mg/100 g.

From this study results, the potassium content of fresh oyster mushroom was found to be 2499.27 mg /100 g. This result is higher than those reported by Khan *et al*. (2008) who observed potassium content to be 1400 mg/100 g. Roy *et al*. (2015) observed fresh oyster mushrooms have 425 mg/100 g potassium content which is lower than the study findings while Çağlarırmak (2007) reported the potassium content in fresh content range between 2225 - 2687 (mg/kg wb). Furthermore, potassium contents were found in abundance as they were observed to be 2490.01 mg/100 g for oven-dried, 2488.44 mg/100 g for sun-dried and 2489.30 mg/100 g for solar-dried mushroom samples. The results are higher than those reported by Roy *et al*. (2015) who found the potassium value in mushroom to be 425 mg/100 g. The value of potassium in dried mushrooms was much higher than the study findings declared by Çağlarırmak (2007) who reported the value of potassium in mushrooms ranged between 12.6 mg/100 g - 29.1 mg/100 g.

Overall, it can be concluded that both sun, solar and oven drying methods have shown potential to retain the mineral composition of oyster mushrooms. However, the solar drying method could be the most commendable. This is because the latter was able in retaining a relatively higher amount of nutrients while protecting the samples from physical contaminating agents.

4.3 Proximate Composition of Maize Flour, Oyster Mushroom Flour and Complementary Flour Blends

The results of proximate composition of maize flour, fresh oyster mushroom and dried oyster mushroom flour and formulated complementary flour blends are shown in Table 4. Fresh oyster mushroom and solar-dried mushroom flour had a significantly higher protein, ash and crude fiber content than blended flours ($p \leq 0.05$). On the other hand, maize flour had a significantly higher content of crude fat, carbohydrate and higher energy value compared to those of fresh oyster mushroom, solar-dried mushroom flour and flour blends. Nonetheless, blending solar-dried mushroom with maize flour improved the composition of crude protein content, total ash and crude fiber contents of complementary flour blends significantly.

Formulated complementary flour blends had significantly higher content of crude protein content, total ash and crude fiber contents than those of control maize flour ($p \leq 0.05$). Increase in protein content of formulated complementary flour blends highlights that blending maize flour with oyster mushrooms increased the protein content. For instance, the blending of maize flour with 30%, 40% and 50% mushroom flour increased protein content in formulated complementary flour blends by 18.20%, 20.37% and 22.75%, respectively. The latter is expected since the mushroom flour had high amounts of protein compared to the maize flour. These results are in close proximity to those reported by Ekunseitan *et al*. (2017), who observed an increase in protein content of cassava and wheat flour proportionately blended with mushroom flour. In a similar study, Bamidele and Fasogbon (2020) reported an 83% increase in the protein content of formulated complementary flour blends of 15% oyster mushroom and 85% maize flour.

Formulated complementary flour blends showed the potential to meet the Recommended Daily Intake (RDI) of protein from complementary foods which is 5.2 g/day at 6–8 months, 6.7 g/day at 9–11 months and 9.1 g/day at 12–23 months of infants who are adequately breastfed (WHO, 2005). This RDI can be met when a 6 – 8 month child will consume 75 g/meal, a 9 –11 month child will consume 120 g/meal and a 12–23 months will consume 200 g/meal of the formulated maize-oyster mushroom complementary food. These proportions compare well with average amounts usually consumed by children of different age groups. However, the proposed feeding proportions could also be influenced by the child's appetite, the caregiver's feeding behaviour and other characteristics such as energy density and the porridges' sweetness (Dewey & Brown, 2003). Thus, the present findings highlight that formulated complementary blends of oyster mushroom and maize as the bulk ingredient flour offer the potential for improving the nutritional level of protein for breastfed infants. Table 4 present the comparative proximate composition data for fresh and solar-dried oyster mushroom, maize flour and complementary flour blends.

Table 4: Proximate Composition of Maize, Fresh Oyster Mushroom, Oyster Mushroom Flour and Complementary Flour Blends

Constituent (%)	Maize Flour (%)	Fresh Oyster Mushroom	Oyster Mushroom Flour (%)	Maize to Oyster Mushroom Flour Ratio		
				70:30	60:40	50:50
Moisture	$9.29^{a} \pm 0.01$	$91.44^{k} \pm 0.60$	$9.45^{b} \pm 0.03$	$9.25^{a} \pm 0.05$	$9.36^{a} \pm 0.04$	$9.49^{ab} \pm 0.04$
Ash	$1.37^{a} \pm 0.12$	$8.83^{b} \pm 0.04$	$8.81^{b} \pm 0.03$	$7.84^{c} \pm 0.05$	$8.11^{d} \pm 0.08$	$8.65^{b} \pm 0.08$
Crude fiber	$7.46^{a} \pm 0.71$	$22.95^{b} \pm 0.01$	$22.41^{b} \pm 0.01$	$15.13^{c} \pm 0.04$	$16.73^{d} \pm 0.23$	$17.91^{e} \pm 0.09$
Crude fat	$4.95^{a} \pm 0.18$	$0.59^{k} \pm 0.002$	$0.38^{b} \pm 0.02$	$4.12^{a} \pm 0.04$	$3.93^{a} \pm 0.08$	$3.81^{a} \pm 0.01$
Crude protein	$8.63^{a} \pm 0.13$	$60.70^{k} \pm 0.01$	$36.42^{b} \pm 0.50$	$18.20^{c} \pm 0.11$	$20.37^{d} \pm 0.50$	$22.75^{e} \pm 0.11$
Carbohydrate	$68.30^{a} \pm 0.75$	$6.93^{k} \pm 0.02$	$22.51^{b} \pm 0.64$	$45.46^{c} \pm 0.06$	$41.50^{d} \pm 0.10$	$37.39^{e} \pm 0.03$
Energy (kcal)	$344.68^{a} \pm 1.84$	$290.61^{k} \pm 0.02$	$246.11^{b} \pm 0.50$	$289.86^{c} \pm 0.41$	$282.13^{d} \pm 1.05$	$275.33^{e} \pm 0.48$

Mean values (n=3) ±SD on a dry weight basis, means in the same row with different letters as superscript are significantly different ($p \leq 0.05$)

The ash content of maize flour was observed to be 1.37%, six - times lower than that observed in fresh and dried oyster mushroom (Table 4). However, the ash content of formulated flour blends increased with an increase in mushroom flour. Ash content increased significantly to 7.84%, 8.11% and 8.65% in 70:30, 60:40 and 50:50 maize to mushroom flour blends. These results corroborate with Bamidele and Fasogbon (2020) who reported that the ash content of flour blends increased by 45.5%, 100% and 236% as the mushroom percentage flour in maize flour increased since oyster mushroom has a higher value of ash. Similarly, Ishara *et al*. (2018) reported 8.56% of ash for oyster mushroom flour that subsequently increased the ash content of formulated flour blends of maize and mushroom. Accordingly, the actual ash content observed in oyster mushroom flour indicates the level of minerals present (Kavitha & Parimalavalli, 2014). Thus, the present finding showed that oyster mushrooms could improve the diet's essential minerals that promote children's health and development.

Crude fiber content increased to 15.13%, 16.73% and 17.91% in 70:30, 60:40 and 50:50 maize to mushroom flour blends, from the initial value of 7.46% observed in maize flour. Increase in ash and crude fiber contents observed in formulated flour blends could be attributed to high fiber content observed in mushroom flour. The fiber content results corroborate with those of Bamidele and Fasogbon (2020) who reported a 36.4%, 90.9% and 227.2% increase in the flour blends as the amount of mushroom flour added to maize flour increased. These findings suggest that formulated flour blends of maize and mushroom may be a good source of dietary fiber due to the renowned high dietary fiber content in mushrooms.

Crude fat content ranged from 3.81% in 70:30 to 4.12% in 50:50 formulated complementary flour blends. The present results for crude fat were not significantly different ($p \geq 0.05$) from that maize flour’s fat content (4.95%), but significantly higher than those of mushroom flour (0.38%). The finding suggest that mushroom and maize flours could be blended quite well in the ratios of 30%, 40% or 50% without altering the fat content present in maize flour. Mushrooms are comprised of low levels of unsaturated fats such as oleic and linoleic acids but very valuable to consumer’s health (Cheung, 2013). Nonetheless, it is recommended that the fat content be limited to 3% to ensure its good quality. High-fat content triggers rancidity during storage producing lousy flavour in the final flour cooked products (Ntuli *et al*. (2013).

The carbohydrate content in formulated complementary flour blends decreased slightly, but significantly with the increase in oyster mushroom flour ratio in the blended flour. Carbohydrate content ranged from 37.39% to 45.46% in 70:30 and 50:50 blended maize-oyster mushroom flours, respectively (Table 4). This could be attributed to low carbohydrate content (22.51%) in the mushroom flour compared to that of maize flour (68.30%). The carbohydrate content observed in oyster mushrooms was slightly lower than those found in 15 selected mushroom varieties from India whose content ranged from 32.43% to 52.07% (Kumar *et al*. (2013). These results highlights that low carbohydrate content could be well complemented by those available maize flour in the complementary blends.

The energy values of the fresh and solar-dried oyster mushroom were found to be 290.6 and 246.11 Kcal, respectively (Table 4). On the other hand, maize had the highest energy value of 344.68 Kcal. Following blending, the energy value of blended maize-mushroom flours ranged from 275.33 - 289.86 kcal for 70:30 and 50:50 maize-oyster mushroom flours blends, respectively. This finding highlights that maize and mushroom flours blending in the present studied ratios could result in a good balance of blended flour energy value. The energy values of complementary blends are within the Recommended Daily Intake (RDI) of energy for infants aged 8 to 9 months of 94.97 kcal/kg (Ikujenlola & Ogunba, 2018). Thus, the present formulated blended maize-oyster mushroom flours of all ratios could meet the Recommended Daily Intake (RDI) requirement for the complementary food.

Moisture is a critical parameter to consider when accounting for the quality of flour and the acceptability of flour products. The latter is the determinant factor for shelf life and microbial growth during the storage of flour and flour products (Aydin *et al*., 2009). In the present study, the moisture content of maize flour was 9.29% where as that of solar-dried oyster mushroom was 9.45%. Blending of maize and oyster mushroom flour did not affect the moisture content of the final product, which ranged from 9.25% to 9.49% for 70:30 and 50:50 blends, respectively. These results are within the range of moisture content recommended by the (World Food Programme ([WFP], 2012) for maize meal flour that should not exceed 15%. Similarly, Ikujenlola and Ogunba (2018) reported that solar-dried mushroom flour's moisture content ranged between 9% - 13%. The low moisture content of maize-oyster mushroom flour blends intended for complementary feeding is critical in prolonging the shelf life and maintaining microbial safety.

The present study did not look at the safety of the formulated maize-oyster mushroom blended flour which is highly susceptible to change during storage. Literature suggests that both maize and mushroom flours are generally vulnerable to rapid moisture uptake and discoloration. Consequently, this leads to mould growth when exposed to humid conditions, thus predisposing the product to loss of quality and safety to consumers (Ojo *et al*., 2017). Nonetheless, documented literature also suggests that storage of maize, oyster mushroom or blended flours in a paper bag, plastic bucket or polyethylene bags under ambient and hot tropical weather conditions offers the chances of better shelf-life stability of flour. Bamidele and Fasogbon (2020) reported that the maize and oyster mushrooms flour blends' storage stability showed that the blend samples were relatively stable at room temperature (25 ºC) for three months with little oxidative deterioration compared to the maize flour alone. Furthermore, Han *et al*. (2016) revealed that oyster mushroom flour had the best storage stability properties (microbial stability, safety, nutritional and functional properties) both at cold (4 ºC) and ambient (25 ºC) storage temperatures. Hence, this highlights that the optimum storage conditions and appropriate packaging of blended maize-oyster mushroom flour should be emphasized to end-users for maintaining the physicochemical properties and overall storage stability properties during storage.

Overall, the finding from this study results (Table 4), it can be concluded that the complementary blends for three studied ratios (30:70, 40:60 and 50:50) of oyster mushroom - maize flour have significant amount of nutrients and can potentially meet the protein Recommended Daily Intake for children. Despite the fact that relatively higher nutrients were observed in 50:50 oyster mushroom flour - maize ratio, the present study revealed that blending of maize flour with 30 or 40% oyster mushroom flour could still offer good results of nutrients as well as energy level of the resulting complementary flour blends.

4.4 Mineral Composition of Maize Flour, Oyster Mushroom Flour and Complementary Flour Blends

The mineral composition of maize flour, fresh oyster mushroom, oyster mushroom flour and the formulated complementary flour blends are presented in Table 5. There was a significant improvement in iron, zinc, calcium and potassium contents in blended flour attributed to mushroom flour enrichment.

There was a significant difference ($p \leq 0.05$) in iron content between the maize flour (3.08 mg/ 100 g) and fresh oyster mushroom (12.85 mg/100 g), oyster mushroom flour (8.31 mg/100 g). Blending of maize and oyster mushroom flours yielded relatively higher amount of iron than that of maize flour, and slightly lower than that of fresh oyster mushroom. The iron content of complementary blends of maize and oyster mushroom flour ranged between 8.30 - 8.73 mg/100 g for 70:30 and 50:50 formulated flour blends, respectively (Table 5). These results suggest that blending maize flour with oyster mushroom flour could be one of the definite means of improving the iron content of traditional cereal-based foods. Ihesinachi and Eresiya (2014) reported that iron is an essential micronutrient that plays a crucial role in haemoglobin formation and oxygen and electron transport in the human body and thus an essential micronutrient for complementary feeding. According to Friel *et al*. (2010) the Recommended Daily Intake (RDI) of iron for infants aged 12 months is 4.6 mg/day which agrees with the iron content of formulated complementary flour blends reported in the present study.

Likewise, there was a significant difference ($p \leq 0.05$) in zinc content between the maize flour (3.51 mg/100 g), fresh oyster mushroom (8.75 mg/100 g) and oyster mushroom flour (8.31 mg/100 g). No significant difference ($p \geq 0.05$) in zinc content observed between the maize flour (3.51 mg/100 g) and the formulated maize-mushroom flour blends. Zinc content increased in the latter to 3.80, 4.12, and 4.54 mg/100 g after blending maize flour with 30%, 40% or 50% of mushroom flour, respectively. High content of zinc observed in oyster mushroom flour could have increased the zinc content in blended maize-oyster mushroom flour blends. Friel *et al*. (2010) recommended that the Recommended Daily Intake of zinc is 4 mg/day for a 12 months aged child. Thus, the present results showed that the formulated complementary flour blends could significantly contribute zinc to infants. Zinc is essential in promoting satisfactory growth and overall maintenance of the human body. Low zinc status in young children has been associated with retarded growth, poor appetite and an impaired sense of taste (WHO, 2010).

The content of both calcium and potassium observed in oyster mushroom flour were significantly higher than those observed in maize flour ($p \leq 0.05$). The former and the latter were 4 and 6 times higher than those observed in maize flour. Further results revealed that blending maize flour with mushroom flour led to increased calcium and potassium contents in the flour blends (Table 5). The content of calcium and potassium in formulated complementary flour blends ranged between 44.59 mg/100 g to 51.13 mg/100 g and 1198.51 mg/100 g to 1214.13 mg/100 g for 70:30 and 50:50 blends, respectively. High content of calcium and potassium in blended flours was attributed to the addition of oyster mushroom flour. As previously reported by Manjunathan *et al*. (2011), potassium composition in mushrooms could be as high as 90.8% of the total mineral content depending on the variety. The present findings suggest that solar-dried oyster mushrooms could be a useful supplement for improving potassium and calcium contents in maize and other cereal flours.

Reports suggest that diets predominantly based on grains and legumes are of particular concern on the quantity of bioavailable micronutrients provided (Ondiek *et al*., 2019). Certain antinutrients such as phytate, hydrocyanides and tannin are present in mushrooms. Nonetheless, the reported levels of these antinutrients are low and unlikely to cause any significant effect on health or to the bioavailability of the nutrients in mushrooms (Ijioma *et al*., 2015; Okon *et al*., 2015). Additionally, Ijioma *et al*. (2015) reported that the consumer might not experience the toxic effect of antinutrients that might be present in complementary maize-oyster mushroom blended flours due to further destruction of these substances during cooking. Furthermore, studies have revealed that maize and oyster mushroom blending does not affect the bioavailability of micronutrients present in the blended flour. For instance, Regula *et al*. (2010) assessed iron bioavailability from cereal products enriched with dried mushrooms. They revealed that the addition of the mushroom significantly increased the bioavailability of iron in the products. These finding highlights that, the blended maize-oyster mushroom complementary food potentially increases the iron bioavailability to malnourished children.

Results in Table 5 highlight that both ratios (30:70, 40:60 and 50:50) of oyster mushroom flour - maize flour contain the significant amount of minerals that potentially meet the iron and zinc Recommended Daily Intake for children.

Table 5: Mineral Composition of Maize Flour, Oyster Mushroom Flour and Complementary Flour Blends

Constituent (mg/100 g)	Maize Flour (mg/100 g)	Fresh Oyster mushroom	Oyster Mushroom flour (mg/100 g)	Maize to Oyster Mushroom Flour Ratio		
				70:30	60:40	50:50
Iron	$3.08^{a} \pm 0.35$	$12.85^{b}\pm0.02$	$12.57^{b} \pm 0.12$	$8.30^{ab} \pm 0.38$	$8.52^{ab} \pm 0.71$	$8.73^{ab} \pm 0.60$
Zinc	$3.51^{a} \pm 0.27$	$8.75^{b}\pm0.04$	$8.31^{b} \pm 0.25$	$3.80^{ab} \pm 0.03$	$4.12^{ab} \pm 0.28$	$4.54^{ab} \pm 0.03$
Calcium	$13.33^{a} \pm 3.41$	$51.87^{b}\pm0.05$	$49.45^{b} \pm 4.22$	$44.59^{ab} \pm 3.13$	$45.04^{ab} \pm 4.11$	$51.13^{b} \pm 5.09$
Potassium	$391.44^{a} \pm 7.22$	$2499.27^{b}\pm0.29$	$2509.67^{b} \pm 10.31$	$1198.51^{ab} \pm 9.14$	$1210.48^{ab} \pm 13.18$	$1214.13^{ab} \pm 11.27$

Mean±SD (n=3) on a dry weight basis, means in the same row with different letters as superscript are significantly different ($p \leq 0.05$)

4.5 Microbial Analysis

The results of microbial load in maize flour, oyster mushroom flour and maize-mushroom flour blends are presented in Fig. 1 and 2. Total bacteria count (TBC) in maize flour ranged between 1.03 - 1.75 cfu/g, whereas that of oyster mushroom flour ranged between 0.4 - 1.77 cfu/g). The total bacterial count in formulated maize-oyster mushroom flour blends ranged between 1.79 - 1.82 cfu/g for 30, 40 and 50% ratios. These results highlight that bacteria counts were below the maximum (5 cfu/g) acceptable counts for flour blends and flour (Ntuli *et al*., 2013).

Total bacterial counts are of significance since they indicate the effectiveness and efficiency of the food chain process and provide information on the shelf life and organoleptic changes throughout the storage time of the food (Batool *et al*., 2012). Higher total bacterial counts exceeding the legal limits indicate poor hygienic practices with the process control and handling of the raw materials and their products.

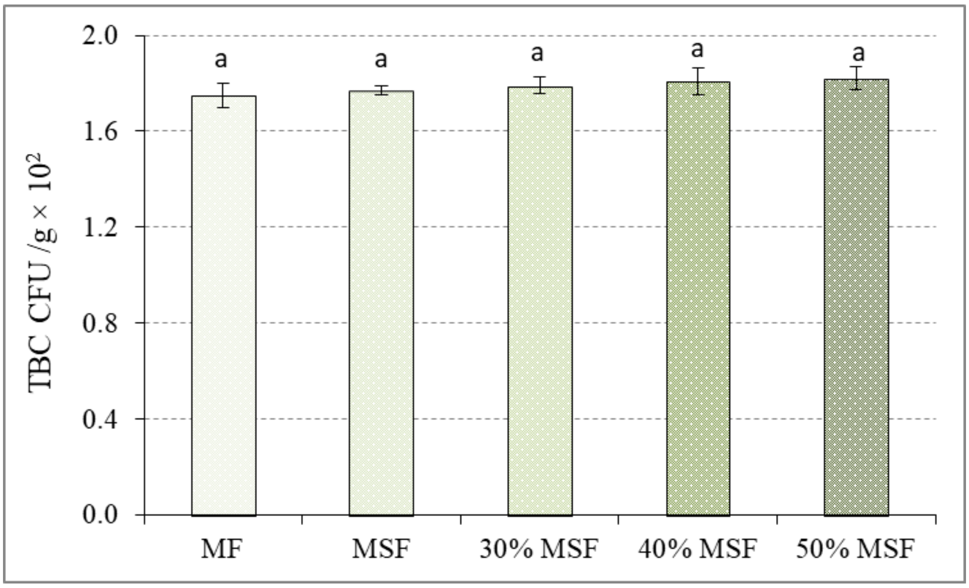

Figure 1: Total Bacterial Count (TBC) of maize flour, oyster mushroom flour and blended flours. Error bars indicate standard deviation from mean value (n = 3) on a dry weight basis. CFU: Colony Forming Unit, MF: Maize Flour, MSF: Mushroom Flour, 30% MSF: 30% Mushroom Flour, 40% MSF: 40% Mushroom Flour, 50% MSF: 50% Mushroom Flour

The results of yeast count for maize flour, oyster mushroom flour and the formulated blends are presented in Fig. 2. The yeast counts in maize flour were 0.39 cfu/g, whereas that of oyster mushroom flour ranged between 0.15 - 0.54 cfu/g. The yeast count in the formulated maize-oyster mushroom flour blends ranged between 0.65 - 0.81 cfu/g for 30%, 40 and 50% oyster mushroom ratios. There was no sign of detection of mould in both samples of flours. Overall, the results of yeast and mould observed in the present study were below the maximum (3 cfu/g) acceptable counts for flours and flour blends (Ntuli *et al*., 2013).

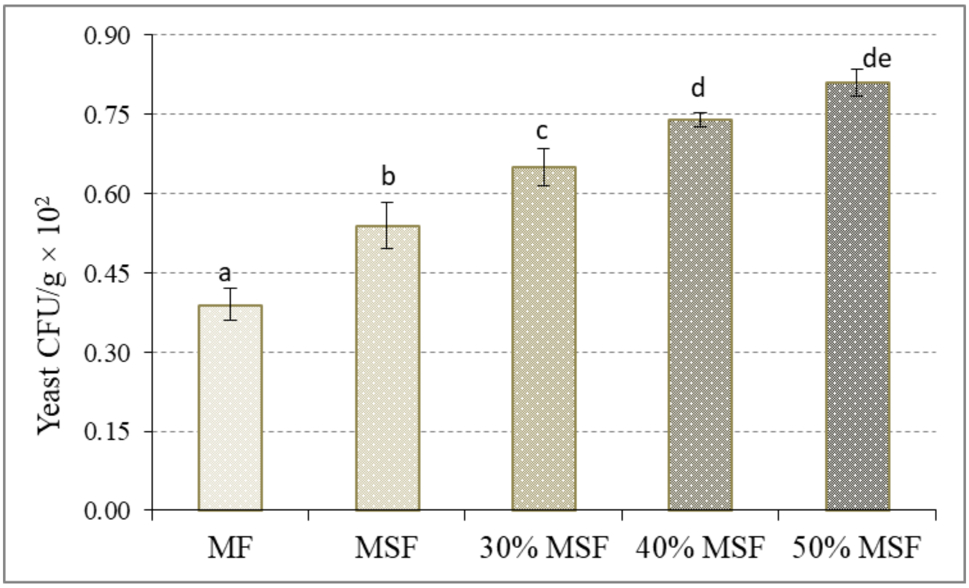

Figure 2: Yeast counts of maize flour, oyster mushroom flour and blended flours. Error bars indicate standard deviation from mean value (n = 3) on a dry weight basis, CFU: Colony Forming Unit, MF: Maize Flour, MSF: Mushroom Flour, 30% MSF: 30% Mushroom Flour, 40% MSF: 40% Mushroom Flour, 50% MSF: 50% Mushroom Flour

Overall, the present results indicate that the formulated maize-mushroom flour blends are safe for use as complementary food for breastfed infants. The levels of contamination of flour by yeasts and molds is of supreme importance when considering the quality and safety of food, as higher levels of yeasts and molds exceeding the legal limits deteriorate the quality of food and causes foodborne diseases. Therefore, enrichment of traditional maize meal with oyster mushroom for complementary feeding could be microbiologically safe if hygienic practices are observed.

4.6 Sensory Evaluation

The sensory evaluation results of the porridges prepared from maize flour and formulated complementary flour blends are presented in Table 7. A significant difference ($p \leq 0.05$) in colour, flavour, aroma, texture and overall acceptability between the control maize meal porridge and formulated complementary flour blends porridge was observed. Preference for colour, flavour, aroma, texture and overall acceptability of samples was the highest in porridges prepared from the control maize meal flour. Formulated complementary foods developed from the three blended flours were relatively the least preferred. The porridges that were developed from 60:40 and 50:50 flour blends had relatively low ratings in most of the quality attributes, mainly colour, flavour and aroma. Nonetheless, the panelists' assessment revealed both formulated complementary flour blends as significant.

Overall, the complementary foods developed from flour blends of maize and oyster mushrooms were not comparable to control (traditional maize flour) porridges. This could be attributed to the effect of oyster mushrooms on the flavour, aroma and colour of the porridges developed from complementary flour blends. The formulated complementary flour blends were nutritionally improved through the enrichment with oyster mushroom, albeit there were some slight alterations in sensory attributes. Some reports revealed that enrichment of cereal flours with mushroom flour tends to decrease the sensory properties. Okafor *et al*. (2012) observed that the ranking of scores for aroma, flavour, texture and overall acceptability of the bread decreased by increasing mushroom powder level in an 85:15 wheat flour to mushroom flour blend. Therefore, blending maize flour with the lowest mushroom flour (30%) may result in complementary flour blends with improved sensory quality suitable for breastfeeding children.

Overall, the sensory evaluation results in Table 7 have revealed that sensory scores of porridge prepared from maize flour porridge (control) and the three formulated flour blends (30:70, 40:60 and 50:50 oyster mushroom flour to maize ratio) indicated good acceptance in the colour, flavour and aroma of the porridges from three formulated flour blends. Nonetheless, the control maize flour porridge and one prepared from 30:70 oyster mushroom flour to maize flour ratio scored the highest by the panelists in all sensory attributes compared to the other two ratios (40:60 and 50:50 oyster mushroom flour to maize ratio). Highest acceptability could be attributed to little or no inclusion of oyster mushroom flour in maize (control) flour and the 30:70 oyster mushroom-maize flour porridges. This highlights that, mushroom could potentially taint the flour of the porridge made from the flour blends, and pronounce a significant mushroom flavour and odour to the porridge. However, this has no effect on the feeding of the formulated complementary flour blends to children.

Table 6: Sensory Evaluation of Porridges Prepared From Maize and Complementary Flour Blends

Attributes	Maize flour (control)	Maize to Oyster mushroom flour ratio		
		70:30	60:40	50:50
Colour	$4.25^{a} \pm 0.16$	$3.80^{b} \pm 0.14$	$3.75^{b} \pm 0.12$	$3.50^{b} \pm 0.18$
Aroma	$4.10^{a} \pm 0.17$	$3.91^{b} \pm 0.14$	$3.84^{b} \pm 0.14$	$3.53^{b} \pm 0.18$
Flavour	$4.45^{a} \pm 0.10$	$3.95^{b} \pm 0.15$	$3.78^{b} \pm 0.13$	$3.57^{b} \pm 0.18$
Texture	$4.40^{a} \pm 0.10$	$3.95^{b} \pm 0.15$	$3.87^{b} \pm 0.15$	$3.75^{b} \pm 0.12$
Overall-acceptability	$4.45^{a} \pm 0.10$	$4.05^{b} \pm 0.16$	$3.85^{b} \pm 0.15$	$3.78^{b} \pm 0.13$

Mean in the same row with different letters as superscripts are significantly different (p <0.05)

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study has demonstrated the nutritional value of oyster mushrooms, their effectiveness and suitability for nutritional enrichment of habitual cereal-based complementary foods, especially maize flour for breastfeeding children. The present results have revealed oyster mushroom as an ingredient of superior nutrient density compared to maize flour. The formulation of maize flour as the bulk ingredient enriched with oyster mushroom improved the nutritional quality of habitual maize-based complementary foods. However, the results have also shown that the blending of oyster mushroom with the maize meal could alter the complementary porridge's sensory properties (viz. colour, flavour and aroma). Overall, this study recommends blending oyster mushroom with maize flour to improve the nutritional content of formulated flour blend for young children who rely on maize porridge as their complementary food.

5.2 Recommendations

There is a need for future study on other nutritional properties of oyster mushroom such as vitamins and phytochemical properties. Future research prospects need is also required towards establishing:

(i) Effect of cooking on alteration of nutritional contents of porridge

(ii) Nutritional assessment of other mushroom species and their potential for complementary feeding

(iii) Product safety (aflatoxin levels and antinutritional factors) and shelf life in different storage regime

Furthermore, advanced research involving children feeding trials to authenticate the nutritional and health-giving properties of mushrooms products produced in the research is also warranted.

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APPENDICES

Appendix 1: Sensory Evaluation Sheet

Nelson Mandela African Institution of Science and Technology (NM-AIST)

Department of Food and Nutritional Sciences

Sensory evaluation of enriched composite maize-mushroom porridge

Sex……………………………………

Age……………………………………

Time……………………………………

Date……………………………………

Please look and taste each of the (3) coded samples. Indicate how much you like or dislike each sample by checking the appropriate sample attribute and indicate your reference (1-5) in the column against each attribute. Put the appropriate number against each attribute.

5 – Like very much
4 – Like
3 – Neither like nor dislike
2 – Dislike
1 – Dislike very much

Attributes	**Sample 1**	**Sample 2**	**Sample 3**
Appearance/ colour			
Flavor/ taste			
Aroma			
Consistence/texture			
General acceptability			

Comments

……………………………………………………………………………………………………
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RESEARCH OUTPUTS

Published Research Article

Siyame, P., Kassim, N., & Makule, E. (2021). Effectiveness and Suitability of Oyster Mushroom in Improving the Nutritional Value of Maize Flour Used in Complementary Foods. *International Journal of Food Science, 2021*.

Poster Presentation

Development of maize-based composite flour enriched with mushroom for complementary feeding.