Biodegradation of Sweet Corn Cob Using Edible Fungi: A Circular Economy Approach

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Being a thesis submitted to the Department of Biological Sciences, Faculty of Natural and Applied Sciences, Lead city University, Ibadan, Nigeria.

In partial fulfilment for the requirements for the Award of Masters in Food Microbiology (MSc Food Microbiology)

2025

Certification

This is to certify that Adenike Abiola **SHOSANYA** with matriculation number LCU/PG/002607 carried out this research work titled "Biodegradation of Sweet corn Cob and Cultivation of Mushroom Using *Pleurotus pulmonarius, Pleurotus ostreatus,* and *Pleurotus citrinopileatus"* in the Biological Sciences Department, Faculty of Natural and Applied Sciences, Lead City University, Ibadan, Oyo State, Nigeria for the award of Masters of Science Degree in Food Microbiology (MSc Food Microbiology) and has not been previously submitted to any institution for the award of any degree or certificate.

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Dedication

I dedicate this research work unto God my Father, my helper, my sustainer and my inspiration.

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Even though the institution and the individuals mentioned above assisted in this course of this research work, I alone am responsible for any mistake or error that might have been committed.

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Abstract

Agricultural wastes (corn cob, rice bran, bagasse) generated from agricultural practices are un-useful and discarded, their accumulation in the environment causes a serious challenge, there is need for eco-friendly waste management solutions which could be achieved through the introduction of the circular economy approach of reducing, re-use and recycling of wastes to produce new valuable products instead of the linear economy where wastes are dumped on the road, in water ways, or burned leading to environmental degradation and loss of valuable organic matter. Agricultural wastes rich in lignocellulosic materials are valueless and indigestible for animals but could be degraded by the lignocellulolytic enzymes in edible fungi. The study investigated the biodegradability of edible fungi (*Pleurotus pulmonarius, Pleurotus ostreatus* and *Pleurotus citrinopleatus)* on sweet corn cob to produce animal feed and protein-rich mushrooms. The parameters analyzed in the study include; rate and extent of biodegradation, lineal mycelial growth rate, analysis of chemical composition, mineral and vitamin content of degraded and undegraded sweet cob. Data obtained were analyzed using one way ANOVA and Excel Spreadsheet Statistical Package in accordance with AOAC official method in complete randomized timeline (988.05). Result shows that the weight of the substrate reduced, mycelial growth rate increased after biodegradation. Cellulose, crude fiber, hemicellulose, ADF, NDF and ether extract reduced due to enzymatic actions on the corn cob. Crude ash, crude protein increased as a result of the reduction in the lignocellulosic content of the sweetcorn cob. Macro minerals; Calcium, Phosphorus, Magnesium increased while Potassium reduced. Micro minerals; Iron, Manganese, Zinc all increased. Fungal colonization markedly increased the level of vitamin content of the substrate. This research shows that fungi (*Pleurotus spp*) are good biodegraders, turning wastes to valuable products in a circular economy enhancing waste management, creating economic opportunities promoting food security and environmental sustainability.

Word count: 298

Keywords: Agricultural wastes, Acid detergent fiber(ADF), Neutral detergent fiber(NDF), Eco-friendly, Circular economy (CE), Linear economy (LE), Lignocellulosic enzymes, Lignocellulosic materials, Biodegradability, Substrate, Sustainability, Edible fungi.

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List of Acronyms

Abbreviations	Meanings
CE	Circular Economy
ACE	Angiotensin Converting Enzyme
DW	Dry Weight
BCAAs	Branched-chain Amino acids
SSF	Solid State Fermentation
ADF	Acid Detergent Fiber
NDF	Neutral Detergent Fiber
LE	Linear Economy
AOAC	Association of Official Analytical Chemists
NIHORT	National Horticultural Research Institute

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Chapter One

Introduction

1.1 Background to the Study

Agriculture is crucial in global food production and feeding the ever–increasing world population, which in turn increases waste generated. Agricultural wastes are plant residues of farm activities such as weeding, clearing, harvesting, and storage of agricultural products, and are known as lignocellulosic residue[1]. They are all parts of crops that are unutilized or underutilized; these include the stem, branches, leaves, stalk, cob and husk[1].

Annually, millions of tons of agricultural waste are generated worldwide which becomes an increasing concern as it causes significant environmental problems due to the fact that they are resistant to microbial and enzymatic breakdown which limits their potential use as valuable materials[2]. There is a need for technologies to turn waste into wealth and reduce its negative impact on the ecosystem[1]. Among these agricultural wastes is the sweetcorn cob whose disposal poses a great environmental challenge due to its high lignocellulosic content (lignin, cellulose and hemicellulose) and slow degradation process[2].

The effect of agricultural waste on the ecosystem is dependent on the available waste and the process of getting rid of them. Most of these agricultural wastes create problems when they are not utilized, poorly utilized or when they are discarded indiscriminately[3]. Open burning of these wastes releases greenhouse gases, increasing the growing concern of global warming currently ravaging the world[2.] It causes respiratory problem when the air is polluted, dumping them on the land attracts harmful organisms which could cause disease outbreak and polluting the ecosystem, dumping on waterways contaminate the water and make it unacceptable as tourist center reducing revenue generation[2].

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Sweetcorn cob is an agricultural waste rich in lignocellulosic materials (lignin, cellulose, and hemicellulose)[1]. It has high content of fiber which makes it undigestible for ruminants however edible fungi (*Pleurotus pulmonarius, Pleurotus ostreatus* and *Pleurotus citrinopileatus*) which has high level of lignocellulolytic enzymes were used to break down the complex compound in the corn cob which makes it useful in the production of animal feed in line with circular economy approach(CE) which offers sustainable and innovative approach to managing agricultural wastes[4]. It advocates reduction, reuse and recycling of wastes in such a way that their life cycle will be extended, minimizing waste and creating new value for previously discarded waste contrary to the linear economy (take-make-dispose)[5]. One major sector where circular economy implementation is essential is in agriculture particularly in the conversion of agricultural wastes into wealth[6]. The approach promotes environmental sustainability, opening of new economic opportunities for farmers and communities[5].

Circular economy involves:

1. Preventing waste and pollution
2. Continuous use of products and materials
3. Recovering natural systems

Based on agricultural context, circular economy encourages the use of organic materials to enrich the soil, generate energy, and produce marketable by-products. Thus, closing the loop and reducing the reliance on synthetic inputs[7].

In the context of this research, edible fungi (*Pleurotus pulmonarius, Pleurotus ostreatus,* and *Pleurotus citrinopileatus*) were used to biodegrade sweetcorn cob (an agricultural waste) to produce animal feed and grow mushroom[5]. These fungi can break down complex materials in the sweetcorn cob to simpler, digestible components[3]. The mycelium of edible fungi naturally decomposes organic matter in the environment,

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playing an important role in nutrient recycling[3]. In a controlled setting, the fungi cultivated on the sweetcorn cob create both an environmental solution for waste management and a nutritional food source[4].

Using edible fungi to biodegrade sweetcorn cob, several benefits can be achieved within a circular economy framework, these include;

1. Contributing to the sustainability of farming practices.
2. Creating an avenue for value–added products (animal feed, mushrooms)
3. Ensuring food security.[8]

1.2 Statement of the Problem

Agricultural wastes are generated in large quantities and their disposal causes significant environmental challenges. Their resistance to microbial and enzymatic breakdown limits their potential use as a valuable material[2]. Thus, there is a need for technologies that could turn waste into wealth and reduce the negative impact of waste on the environment, this brought up the circular economy approach instead of the existing linear economy[5].

1.3 Aim and Objectives of the Study

This study explores the biodegradation of sweetcorn cob using edible fungi (*Pleurotus pulmonarius*, *Pleurotus ostreatus,* and *Pleurotus citrinopileatus*) and to evaluate their effectiveness in mushroom cultivation, promoting sustainable waste management and food production to achieve a circular economy.

The objectives of the study are to:

1. To evaluate the rate and extent of biodegradation of sweetcorn cob under controlled conditions.
2. To evaluate the mycelial growth rate at intervals.

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3. To carry out the chemical composition analysis of substrate before and after degradation.
4. To determine the mineral and vitamin content of degraded and undegraded cob.

1.4 Justification of the Study

The research addressed the global challenge in waste management by exploring a solution (circular economy approach) to efficiently use the sweet corn cob wastes which are discarded to produce nutrient-rich animal feed and high value food (mushroom), improve economic viability of agricultural practices which will enhance sustainable development, environmental conservation and food security making the research a relevance and a timely one[3].

1.5 Significance of the Study

1. This research is significant because it enhances waste management and environmental sustainability by converting wastes to renewable resources[5]
2. It promotes natural decomposition through fungal enzymes, leading to the breakdown of organic materials in the sweet corn cob[9]
3. It makes way for converting waste to wealth (production of animal feed and used as substrate for mushroom cultivation) an avenue for revenue generation for farmers with increased profitability[6].
4. Mushrooms cultivated rich in protein, vitamins, and other essential nutrients, offer a sustainable food source and an additional source of protein to man and animal[8].
5. It provides insight into the circular economy, where wastes are converted into valuable products, minimizing waste and pollution.

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1.6 Scope of the Study

Investigation of edible fungi *(Pleurotus pulmonarius, Pleurotus ostreatus*, and *Pleurotus citrnopileatus* ability to degrade sweetcorn cob which is an agricultural waste in the solid-state fermentation process[3]. The scope covers the monitoring of fungal colonization, mycelial growth rate and the effect of biodegradation on substrate composition to determine the efficiency of fungal bioconversion and biotransformation in a circular economy approach, which emphasizes reduction, reuse and recycling of agricultural wastes to produce valuable products (animal feed and edible mushroom)[6].

1.7 Limitations of the Study

1. **Scale of experiment**: The work was limited to laboratory scale-controlled conditions, which might not accurately represent the occurrences in industrial-scale mushroom cultivation.
2. **Use of limited fungal species:** There are other fungi (edible and non–edible) which are good biodegraders, such as *Trametes versicolor,* that could be used instead of limiting the research to the *Pleurotus* species only.
3. **Lack of safety assessment**: Toxicological examination and evaluation were not carried out on the fungal biomass or spent substrate to determine if harmful metabolites such as heavy metals, mycotoxins are present in it which might affect the safety of the food or feed.
4. **Limited period of monitoring biodegradation process**: A long period of monitoring and studying fungal colonization of the substrate could give more information on complete substrate utilization and variations in fungal physiology.

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5. **Use of homologous substrate**: This could affect the fungal colonization, enzymatic efficiency and the result of the final yield because agricultural residues are heterogeneous.

1.8 Operational Definition Of Terms

Circular Economy: Is a system aimed at reducing, reusing and recycling wastes from agricultural practices to productive materials.

Agricultural Wastes: Non-useful products from farming practices such as corn cob, stalk, leaves animal manure.

Lignocellulosic Materials: They are complex materials in agricultural wastes (lignin, cellulose and hemicellulose).

Edible Fungi: Fungi that are safe and fit for human consumption such as *Pleurotus pulmonarius,* to break down the complex content in the agricultural wastes.

Lignocellulosic Enzymes: Enzymes produced by some fungi, such as *Pleurotus spp.* To break down the complex content in the agricultural wastes.

Biodegradation: The Process of breaking down agricultural wastes by fungi into simpler compounds such as carbon dioxide, nutrients and water.

Substrate: Is a platform on which organisms can grow or feed. Corn cob is an example of a substrate on which fungi can grow.

Digestibility: The measurement of the ability of animals to break down food, plant materials and absorb them.

Biodegradation: The Process of breaking down agricultural wastes by fungi into simpler compounds such as carbon dioxide, nutrients and water.

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Substrate: Is a platform on which organisms can grow or feed. Corn cob is an example of a substrate on which fungi can grow.

Composting: Breaking down of organic wastes by microorganisms into nutrient-rich material known as compost useful as a fertilizer to nourish the soil.

Sustainable Farming: Farming practice of producing food in a way that protects the environment, conserves resources and supports the ecosystem.

Solid-state Fermentation: A method where microorganisms are grown on solid materials without free-flowing water.

Decomposition: The Process of breaking down organic materials into simpler substances. It recycles nutrients back into the environment.

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Chapter Two

Literature Review

2.1 Agricultural Waste

Wastes originating from agricultural activities are residues from agricultural activities . These include crop residue, animal residue, waste from processing industries[1,2]. As a result of the presence of biologically active compounds in agricultural waste, they serve as an alternative source for the production of different useful products like biogas, biofuel and other products that are useful for research and industries[2]. Recently, long-term environmental sustainability and the nation's growth enhancement have been of great importance. This development has brought about more focus on waste disposal and the conversion of waste into value-added products. Improperly disposed agricultural waste can lead to environmental pollution that poses serious health challenges, safety in the environment. Although agricultural products are very important in human and environmental development because of the increasing human population, an increase in agricultural production also results in an increase in agricultural waste, which has raised awareness among researchers around the world on the importance of proper waste management.

2.1.1 Types of Agricultural Waste

Agricultural wastes are classified into; Wastes from plants, animal and processing industries[5]

1. Post-harvest agricultural waste: Post-harvest agricultural waste is the quantitative and qualitative waste at any point in time from the harvest of crops to

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consumption. Crop waste contains leftovers from crop production and processing, like husks, stalks, grains, leaves and cobs of crops.

2. Agro-industrial residue: Agro-industrial residue such as sweetcorn cob, is waste that is obtained from the processing of crops into food and they are also byproduct from food industries which includes peels, oil-cakes among others.
3. Animal wastes: These include bones, blood, hair/fur, hoof and excreta of animals are wastes from abattoirs.

2.1.2 Sources of Agricultural Waste

The size and composition of the waste generated depends on the type of agricultural activity that was conducted.

1. Waste produced during preparation of farmland for agricultural purposes: These include waste from containers of herbicides, weeds, excess manure or fertilizer which contaminates water and land[5]. For example, food contamination is a result of uncleanliness in handling food, contaminated farmland and extreme use of manures.
2. Waste from production livestock: This includes solid wastes such as excreta, water used in washing cage, pen house and animals [5]. These wastes when left untreated can release harmful substances which could affect the ozone layer, the soil nutrients, render water un useful, spread human and animal diseases and finally, disrupting the ecosystem.
3. Aquatic waste: The metabolic waste is paramount in water, it could be suspended or broken[7]. Temperature is one of the basic factors which influences the feeding ability of animals. The increase in the temperature of the environment increases the rate of food consumption of animals as well as the wastes produced.[1] . The

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waste produced should be used immediately or preserved in a condition that will avoid spoilage and maintenance of its quality for future use[8]. There are numerous ways in which this agricultural waste can be properly utilized\

1. To boost sol fertility
2. To get rid of heavy metals
3. For pyrolysis (allowing agricultural waste to pass through heat at 400°c to 600°c) .
4. Can be used as feed for animals
5. Substrate for growing mushroom

2.1.3 Effects of Agricultural Wastes on Human Health and the Environment

1. Lack of proper treatment of agricultural wastes causes soil contamination, water pollution, biodiversity loss which could adversely affect food creation[3].
2. Greenhouse gas discharge causes global temperature rise, ocean acidification, threatens food production.
3. Indiscriminate burning of wastes releases toxic gases, chemicals into the environment which pollutes the air, soil and water damaging the ecosystem.
4. Blocking of water ways by solid wastes can result into flooding, contamination of water bodies making them unfit and unsafe for use.

2.2 Agricultural Waste Management

Agricultural waste management is the strategic handling, reuse or valorization of agricultural waste to produce value-added products in order to maintain a sustainable environment and agriculture[12]. Effective management of agricultural wastes is to recycle them into useful products which include practices such as composting, edible fungi

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cultivation, non-conventional feed ingredients, traditional soap making, alternative energy sources, biofuel production, production of silica, among others[1,12,13]. A standardized efficient agricultural waste management system would advocate for food security and the energy supply chain, besides curbing environmental pollution[14]. An increase in large-scale production activities requires specialized waste collection and management systems. Management of waste is a serious problem that needs various efforts to be combined for it to be effectively implemented[9]. Application of low-waste technologies in agribusiness requires the exploitation of agricultural products, helping to mitigate environmental problems and cut costs in food and drug production[14].

2.2.1 Ways of Managing Agricultural Wastes

These include: pyrolysis, landfill/sanitary landfills, compost, incenaration[15,16].

1. Pyrolysis: This is the process of heating waste to a high temperature (400-1000 °C)[17]. It is different from combustion because combustion takes place in the presence of oxygen.
2. Landfills/Sanitary landfills: This is a site where waste is dumped in layers in a pit and covered for final disposal (a place designed for processing solid wastes). Landfill slowly evolved over the years by proper siting, design and management into effectively and efficiently operated bioreactors to produce CH_4 (Methane) useful for fuel, and leachates which were treated biologically and with chemicals to minimize groundwater[15].
3. Compost: Composting is the process of using an aerobic (in the presence of oxygen) method to decompose organic solid or liquid waste. Suitable ingredients or chemicals are designed to improve the processes of composting[16]. It is an effective and aged method for turning wastes into valuable products[14,16].

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Biological method of composting is well known; it is carried out under aerobic conditions to stabilize organic substrate into a product with fertilizer properties, called compost[16].

4. Incineration: This is a treatment technology which involves the destruction of solid waste through controlled and monitored burning at high temperature, accompanied by the release of heat, which can also be a source of energy[17]. Older incinerator technology and especially poor maintenance practices during incineration have been strongly connected to adverse health effects and disruption of the earth's ozone layer, while more recent incinerator technology is increasingly used to manage waste as well as produce electricity[10,14].

2.2.2 Benefits of Waste Management

1. Reduces after-harvest losses
2. Helps in the proper utilization of produce
3. Reduces problems of collecting waste and decay
4. Prevention of environmental pollution[3]
5. Maintenance of proper sanitation and hygiene[18]
6. Recovery of vital substances
7. Production of value-added food products[1,11]
8. Increase profits for industries

2.3 Circular Economy

A circular economy is an economic model that is focused on reducing or minimizing waste while producing new products in place of the old or traditional "take, make, dispose approach[19]. It focuses on:

1. Reducing resource use

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2. Reuse of products and materials
3. Repairing and refurbishing items
4. Recycling wastes into new resources[20].

All these dwell on the following:

1. Design for longevity, that is, products are made to last longer, be repaired or upgraded easily.
2. Reuse and repair of materials instead of throwing them away.
3. Recycling, which means that materials are recovered and reused to make new products, minimizing the need for raw materials[20]
4. Waste as a resource: What is considered waste in one system can be a raw material in another. This provides an avenue to see goodness in wastes[20].

2.3.1 Why the Need for a Circular Economy?

1. Scarcity of natural resources: Natural resources are limited in supply, hence the need for waste re-use and recycling[19].
2. Impact on the environment: One prominent aftermath of traditional production or use of old practices in production is environmental pollution, as well as landfill issues and emission of greenhouse gases that deplete the ozone layer, which altogether lead to health issues[21].
3. Economic benefits: Reduction of wastes can reduce costs and lead to the creation of new business opportunities[19].

2.3.2 Application of Circular Economy to Agricultural Wastes

1. Production of bioenergy: Residues from agricultural practices can be converted to biofuels, for example, biogas, biomass pellets or bioethanol. A very good example

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is the use of manure or crop waste in an anaerobic digester to produce biogas used for electricity[22].

2. Soil improvement and composting: Organic wastes are composted to create nutrient-rich soil, decreasing the need to fertilize the ground using chemical fertilizers[23]. This ensures a tight, well-controlled, and close nutrient cycle by returning nutrients into the soil[19,23].
3. Animal feed: Some by-products of agricultural activities, for example, peel, shafts, cobs and spent grains, can be reused and compounded as feed for animals[24].
4. Production of bio-based materials and chemicals: Agricultural wastes can be used to create biodegradable packaging of products, bio-plastics, bio-chemicals, bio-utensils as well as other bio-products[22]. For example, corn husk can be used to make paper and packaging materials.
5. Water recycling: Waste water from agricultural processing can be treated and reused for irrigation or cleaning[20].

2.3.3 Mode of Operation of Circular Economy

This is based on the principle of ensuring the availability and efficacy of resource, protecting the continuity of nutrients, promoting ecosystem sustainability and decreasing the harmful effect of agricultural waste on the environment [25]. This principle primarily changes the normal linear way of farming to circular economy where there is zero-waste generation[19]. The circular economy is important and essential in that it is deeply rooted in sustaining farming practices to ensure long-term ecological and economic stability[26]. The modes of circular economy approach include;

1. Nutrient Cycling

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An important aim of circular economy is the continuous movement of nutrients within the ecosystem[27]. In the linear economy model, nutrients are lost as a result of runoff or erosion resulting in the degradation of the soil causing water pollution and reduced soil fertility[23]. Circular economy on the other hand emphasizes on reducing, reuse and recycling agricultural wastes. This could achieved when organic materials which include plant wastes, animal wastes and wastes from production industries are reused, recycled and transformed into valuable materials such as organic fertilizers [19,23]. Composted organic matter can be used to boost the nutritional content of soil leading to increased productivity, this will reduce the use of synthetic fertilizers, washing away soil nutrients and general reduction of pollution which ensures sustainable agricultural practices[23]. In agroecological farming where animal production and plant production occurs simultaneously, there will be nutrient cycling through mixed crop-livestock systems thus integrating animal husbandry with crop production[28]. In this type of system, animal wastes serve as source of phosphorus and potassium which are nutrients needed by plants generally to grow well[29].

2. Minimizing the Use of Chemicals

A circular economy approach is aimed at reducing the dependence of farmers on external inputs, especially fertilizers, pesticides, herbicides and insecticides which cause havoc to the land as they contribute to soil nutrient depletion, soil degradation, reduction in biodiversity and pollution of water and land[29]. It focuses solely on using traditional agricultural practices where the use of chemicals is reduced or eliminated to achieve a healthy soil, food production and also a healthy ecosystem[28].

3. Waste Reduction

Another mode of operation of circular economy is to reduce waste by making sure that all leftover from agricultural practices are reused. This practice ensures nothing is regarded

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as waste which is in support of the zero-waste generation approach where all materials are reused, recycled sustaining cordiality in the ecosystem[30]. Plant wastes including corn cob, stalk and husk that are regarded as waste in the traditional farming system are useful products in the circular economy system[26]. The waste materials left on the soil surface helps in soil water retention (while also adding nutrients to the soil as they decay), suppresses weeds and improves the structure of the soil by increasing its nutritional content and the activities of microorganisms[31]. Waste originating from livestock can be used to produce biogas[32]. This serves as a source of renewable energy for agricultural activities and also produces nutrient-rich substrate useful as fertilizer[23].

2.3.4 Advantages of Circular Economy in Agriculture

The circular economy has a lot of benefits that makes it a better option over the linear economy, these include;

1. Improvement on Soil Health/ Healthy Soil

Minimizing the use of chemicals in agricultural practices enhances healthy soil[33]. Traditional farming practices such as composting, planting of cover crops and crop rotation helps in adding to and retaining soil nutrients, increasing soil organic matter and improve soil moisture[24]. Soil that is healthy have the ability to withstand drought and erosion can store more carbon thereby contributing to the mitigation of climate change and depletion of the ozone layer[34].

2. Greenhouse Gas Emission Reduction

Circular economy helps in reducing emission from greenhouse gas through reduction in using artificial soil enrichment products such as fertilizers and adoption of agro forestry and ecological farming practices which focuses on enhancing soil health and ecosystem improvement[35] .

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3. Water Management

The non-availability of water is a predominant challenge in agriculture practices. The circular economy system provides solution to this heartache by encouraging efficient use of water through practices such as drip irrigation, reuse of effluent which helps to reduce the rate at which water is utilized thus increasing crop yield[26]

4. Biodiversity Conservation

Biodiversity conservation is the process of protecting and preserving various species of plants, animals , microorganisms and their ecosystem so as to preserve them for present and future use. The concept of circular economy supports the co-existence of organisms in the ecosystem and protects them from environmental influences[26,33,36].

5. Economic Sustainability

The use of natural agricultural practice approach such as composting, natural pest controls helps in reducing cost incurred on agricultural practices. Also, the use of various farming methods like crop rotation, planting of cover crops increases the soil fertility thus reducing the expenses on soil nutrient enhancers[37].

2.3.5 Barriers in Effective Implementation the Circular Economy

Circular economy approach has numerous advantages however there are various challenges facing its implementation which includes;

1. Lack of Awareness

Most farmer lacks proper orientation, technical skills, resources and the knowledge required to adopt the circular economy practices. Awareness and educative programs should be organized for the farmers to enlighten them on the concept and importance of circular economy as well as its advantages over the linear economy[26].

2. Economic Limitations

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The integration of circular economy approach technologies into agricultural practices requires a huge financial investment at the initial stage. The government, NGOs and institutions need to assist the farmers by providing financial support, introducing subsidy on farming implements and materials to encourage adoption of the approach[38].

3. Policy Formulation

Policies and laws that promotes circular economy should be formulated to encourage and protect sustainable farming practices. The government can reduce the tax payable on the raw materials, grant little or no interest loan to farmers, subsidies for farmers adopting circular practices which serves as platform for sustainable agriculture[26].

4. Marketability of the Products of Circular Economy

The products of circular economy approach must be widely accepted. Consumer awareness and education programs, products certified and well labelled can help in creating markets for products.

2.3.6 The Prospect of Circular Economy Practices

The circular agriculture has a promising future in that there is rise in awareness globally on its impact in waste reduction, reuse and environmental conservation[26]. There will be emergence of technologies where wastes will be fully utilized to produce valuable products that will be accepted by the consumers, creation of pollution free environment and restoration of ecosystem. There will be collaboration internationally and sharing of ideas among countries which will drive new innovation and scale-up circular economy practices globally[33].

2.4 Sweetcorn

Sweetcorn (*Zea mays saccharata*) is a starchy food kernel which can be regarded as vegetable when it is fresh and as grain when it becomes dried. It has high sugar content

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and the kernel can retain high level sugar than the widely cultivated corn due to its genetic mutation[39]. Fresh sweetcorn originated in the United States of America and has since been introduced to other countries around the world[40]. Agricultural residue generated from sweetcorn includes; the leaf, stalk, cob, husk, and leftover kernels[41]. These agricultural wastes become environmental pollution if left unused, untreated or under-utilized[42]. In recent times degradation of agricultural wastes using fungi is of great importance in the management of waste. It is a process by which the complex compounds in the waste are broken down to simpler compounds through the activities of living microbial organisms[43].

2.4.1 Classification of Sweetcorn

Sweetcorn is a monoecious, single-stem plant belonging to the same family as grass. The life cycle of sweetcorn consists of the vegetative and the generative phase, the classification goes as follows[44]:

Kingdom: Plantae

Phylum: Tracheophyta

Class: Liliopsida

Order: Poales

Family: Poaceae

Genus: *Zea*

Specie: *Zeamays*

Sub species: *Zea mays* sub specie *mays*

Group: Saccharata

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2.4.2 Morphology of Sweetcorn

Maize belongs to the grass family, the leaves grow on opposite sides of the stalk with one leaf per node, the sweetcorn plants develop grains on the lateral branches.[45]. Sweetcorn has inflorescences of male and female on a particular plant this means it is monoecious in nature. Maize and sweetcorn have similar morphology, however the absence of some alleles that distinguish sweetcorn from maize by increasing the sugar content in maize. The plant is characterized by several key components: the tassel, ear, kernel, stem, leaves and roots each playing a vital role in the plant's life cycle and productivity[45].

The tassel which is the male flowering part of the plant emerges from the top and is responsible for shedding pollen. This pollen is necessary for fertilizing the ovules which are contained within the ears, the female reproductive parts of the plant. The ears develop lower on the plant and are covered by husks protecting the developing kernels which are the edible part of the plant and the primary reason for its cultivation, they are attached to the cob which is the core of the ear around which the kernel grows[46].

The stem or stalk supports the entire plant and is useful in transporting nutrients and water from the root to the other part of the plant, the leaves broad and capture sunlight for photosynthesis, a process needed for plant growth and development of the kernels[45,46].The root is the anchor for the plant, provides minerals and water for the plant, there is also the brace roots that emerge above ground to stabilize the tall plant[45].

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2.5 Sweetcorn Cob

Sweetcorn cob is an agricultural waste, has high dietary fiber, phytochemicals and minerals[47]. It consists of cellulose, hemicellulose, lignin, moisture and residual sugars[48]. The lignocellulosic composition makes corn cobs a good carbon-rich substrate but they are relatively low in nitrogen. Its uses include:

1. Animal feed production
2. Feedstock for energy generation
3. Bio-oil generation
4. Carbohydrate source to produce chemical building blocks, enzymes and waste water such as heavy metal dyes[49].

Sweetcorn cobs like many other lignocellulosic agricultural residues contain a variety of minerals though generally in low concentrations compared to grains or leaves[50]. Typical minerals found in sweetcorn cobs include:

Table 2.1: Mineral Composition of Sweetcorn Cob

Mineral Element	**Approximate Content (mg/kg dry weight)**	**Notes**
Calcium (Ca)	200-1000mg/kg	Important for cell wall stability; buffers pH
Potassium (K)	500-1500mg/kg	Vital for enzyme activation and osmotic regulation
Magnesium (Mg)	100-300mg/kg	Co-factor in many enzymatic reactions
Phosphorus (P)	200-600mg/kg	Essential for energy metabolism (ATP)
Iron (Fe)	10-50mg/kg	Important for respiration and electron transport
Manganese (Mn)	10-40mg/kg	Involved in enzyme systems
Zinc (Zn)	5-20mg/kg	Enzyme cofactor, important for growth
Copper (Cu)	2-10mg/kg	Enzyme cofactor
Sodium (Na)	Usually low (5-30mg/kg)	Present in small amounts

Values vary depending on corn variety, soil conditions, and cob maturity.

Source[44]

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2.5.1 Phytochemicals in Sweet Corn Cob Relevant to Fungal Cultivation

Sweetcorn cobs are rich in diverse phytochemicals some of which may serve as nutritional or stimulatory factors for fungal growth especially in the context of solid-state fermentation (SSF) or biodegradation[47]. While sweet corn kernels are more nutritionally dense, the central core of the maize ear contains a variety of bioactive compounds and nutrients that can support fungal colonization and metabolism[51]. These phytochemicals include:

Phenolic Compounds

Phenolics in corn cob is a carbon source for some fungi especially white-rot fungi and *Aspergillus* species, which can degrade lignin and other aromatic structures.

1. Ferulic acid – major phenolic acid in corn cob, it can act as a precursor for fungal biotransformation.
2. p-Coumaric acid – metabolized by fungi like *Aspergillus niger*.
3. Vanillic acid – an oxidized phenolic compound; certain fungi can convert it into vanillin-like aromatic compounds[52].

Cellulose and Hemicellulose

These are polysaccharides and form the major carbohydrate matrix of the cob[53]. Many fungi produce cellulases and xylanases to break these down for nutrition.

1. Cellulose – degraded by cellulolytic fungi (e.g., *Trichoderma reesei, Aspergillus fumigatus*).
2. Xylan (a hemicellulose) – hydrolyzed by xylanase-producing fungi like *Aspergillus and Penicillium spp*[54].

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Lignin-associated Phytochemicals

Lignin, though recalcitrant, is partially degraded by lignocellulolytic enzymes in white-rot fungi such as *Phanerochaete chrysosporium*. Its degradation releases soluble phenolics and aromatic compounds.

1. Guaiacyl and syringyl units – common in lignin which is been broken down by fungi to access energy.
2. Hydroxycinnamic acids – serve as electron donors or inducers of lignin-degrading enzymes.

Flavonoids (Minor Amounts)

Although present in smaller quantities in cobs compared to kernels, flavonoids can sometimes act as enzyme inducers for fungal bioconversion[55]. Quercetin and kaempferol derivatives may modulate enzyme expression in some fungi.

Tannins and Saponins (Trace)

These compounds can have dual effects: low levels stimulate fungal growth while high concentrations may be inhibitory. Corn cobs generally contain low levels that may be metabolized[56].

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Table 2.2: Phytochemicals in Sweet Corn Cob

Phytochemical Group	Specific Compounds	Role in Fungal Cultivation	Fungi That Utilize
Phenolic Acids	Ferulic acid, p-Coumaric acid, Vanillic acid	Act as a carbon source, enzyme inducers, and antioxidants	*Aspergillus niger, T. versicolor, Fusarium spp.*
Cellulose	β-1,4-glucan chains	Primary carbon source; digested by cellulases	*Trichoderma reesei, Aspergillus fumigatus*
Hemicellulose	Xylan, arabinoxylan	Broken down by xylanases into xylose	*Penicillium, Aspergillus spp.*
Lignin Compounds	Guaiacyl units, syringyl units	Electron donors, enzyme inducers for ligninolytic fungi	*Phanerochaete chrysosporium, Pleurotus spp.*
Flavonoids (Trace)	Quercetin, Kaempferol	Enzyme modulation, antioxidant roles	*Aspergillus oryzae, Basidiomycetes*
Tannins (Trace)	Hydrolysable tannins	Low doses support fungal growth; metabolized as a carbon source	*Rhizopus, Mucor spp.*
Saponins (Trace)	Various triterpenoid saponins	May serve as surfactants or mild	*Aspergillus, Trichoderma spp.*

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enzyme activators

Source[50]

Table 2.3: Vitamins in Sweet Corn Cob and Their Role in Fungal Cultivation

Vitamin	Presence in Sweet Corn Cob	Role in Fungal Cultivation or Biotransformation
Vitamin C (Ascorbic Acid)	Low to moderate – reduced compared to kernels	Antioxidant: can protect fungal cells during oxidative stress
Vitamin B1 (Thiamine)	Present in trace amounts	Coenzyme in fungal carbohydrate metabolism
Vitamin B2 (Riboflavin)	Present in trace amounts	Supports energy production and metabolic processes
Vitamin B3 (Niacin)	Present – retained during maturity	Helps in NAD/NADP synthesis in fungi
Vitamin B5 (Pantothenic Acid)	Present – low levels	Involved in fungal fatty acid metabolism
Vitamin B6 (Pyridoxine)	Present – trace but metabolically significant	Supports amino acid metabolism in fungi
Vitamin B9 (Folate)	Moderate – can be used in fermentation	Crucial for DNA/RNA synthesis in rapidly growing fungi
Vitamin A (Carotenoids)	Low – carotenoids decrease with maturity	May act as a pigment precursor or an antioxidant
Vitamin E (Tocopherols)	Present in trace amounts	Acts as an antioxidant; stabilizes fungal cell membranes

Source[50]

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2.5.2 Advantages of Corn Cob for Fungal Cultivation

1. It is cheap and abundant in nature.
2. It has a good structure which provides a ratio and moisture retention for fungal growth[24].
3. It is rich in cellulose and hemicellulose which can be readily digested by fungi for growth[48].
4. It is waste sustainable and promotes the circular economy[19].
5. Their dense texture compared to loose straw helps to lower contamination chances.

2.6 Fungi

Fungi are saprophytic and decomposing organisms that can easily adjust to any situation and grows at a fast rate . They produce several enzymes such as cellulase, catalase, lipase and others useful in the biological control of nematodes, plant pest control[57]. Fungi are good decomposers; recycling organic matter and through mycorrhization process provides food for plants[58].

Fungi produces enzymes (lignocellulolytic enzymes) that breaks down the residues in plants (lignocellulosic residues) which is difficult to digest by animals but could be turned into a simpler form through the process of degradation by fungi, depending on the substrate and the enzymatic system[24].

Mushrooms are fungi from the kingdom Mycetae, they are edible and non-green fungi. They are neither plants nor animals because they lack chlorophyll and they are able store glycogen. They contain about 90 % moisture which makes them highly perishable. It contains high protein, high fiber content, vitamins and minerals[59]. Not all mushrooms are edible, the non-edible or poisonous mushroom like toadstool produce toxins and can be

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deadly if consumed. Mushroom can be cultivated on biodegraded substrates and growing naturally on log of wood.

Fungi are saprophytic in nature, they are also decomposing organisms that grows at a fast rate on the substrate, adjusting to all conditions[58]. They produce several enzymes such as cellulase, catalase, lipase and so on useful in the control of plant pests, nematodes and enzymes used in degrading agricultural wastes such as lignase, cellulases[60].

2.6.1 Introduction of Mushroom (*Pleurotus species*)

They are mushrooms that could be eaten or are safe for consumption[61]. They are rich vitamins, protein, minerals and essential chemical compounds which characterize them as healthy food[62]. They are highly medicinal and grow in various habitats; on decaying wood, forests and agricultural wastes[63]. There is a need for proper identification to avoid the poisonous ones. Examples of edible mushroom are: *Agaricus bisporus, Lentinula edodes, Pleurotus species Hericum erinaceus* and many more[64]. They convert agricultural wastes to nutritious food and the spent compost used as animal feed or biofertilizers[65]. They combine nutritional, health benefits and the ability to recycle agricultural wastes to ensure food security and sustainability[26].

2.6.2 Classification of Edible Fungi (*Pleurotus* species)

Also known as oyster mushroom and saprophytic in nature.

Kingdom	Fungi
Phylum	Basidiomycota
Order	Agaricales
Family	Pleurotaceae
Genus	*Pleurotus*

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Some well-known mushrooms include;

1. *Pleurotus pulmonarius*
2. *Pleurotus ostreatus*
3. *Pleurotus citrinopileatus*
4. *Pleurotus djamar*
5. *Pleurotus sajor-cajn*

They feed on dead or decaying wood and could also be cultivated on agricultural wastes such as straw, corn cobs and sawdust. They grow on various substrates within the shortest time. They are rich in protein, vitamins, minerals and dietary fiber.

Examples of edible mushrooms of Pleurotus species include:

1. *Pleurotus ostreatus* (Blue Oyster Mushroom):

P. ostreatus produces enzyme useful in industries such as laccase useful in decolorizing dye named anthraquinone. Major elements such as; phosphorus, calcium, and potassium are of low concentration in it but trace elements such as; boron, magnesium, cadmium, iron and manganese are of higher concentration. It is of great use in biodegradation, immune-modulatory, anti-hypocholestrolemic, anti-mutagenic and anti-tumor activities[66].

2. *Pleurotus pulmonarius* (Phoenix Oyster Mushroom):

It is also referred to as the Indian Oyster mushroom, similar to *Pleurotus ostreatus* but with few distinct differences. It has a smaller cap and prefers warm environment[67]. They also have similar mode of cultivation, widely spread in temperate and sub-tropical forests in the entire world. In Eastern United State, it is common on hardwoods and on the confers in the Western United State[67].

β-D-Glucan which is a polysaccharide found in *P. pulmonarius* can reduce mice sensitivity to pain which is a basis for new analgesic medications. Extracts from *P. pulmonarius* can hinder the proliferation of cancer cells and diabetes. It is also effective

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in treating hay fever and inhibits the release of histamine causing reduction in sneezing, nasal rubbing and has antimicrobial properties[68].

3. *Pleurotus Citrinopileatus* (Golden Oyster Mushroom):

This is referred to as the golden oyster mushroom. It is a popular wild edible mushroom, native to subtropical forests and prefers warmer environments. It grows at a temperature around 26 °C and fruiting bodies formed at a temperature of 18-32 °C[69].

Fungi lacks chlorophyl and could not manufacture their own food, they act as parasitic or saprophytic organisms in nature with total dependence on other various living organisms for their source of food. Saprophytes are good bio-degraders, they can degrade any organic substance through their enzymatic batteries[70]

2.6.3 Substrates for Cultivating Mushroom

There are various substrates on which mushrooms can be grown, they have lignocellulosic materials that supports the growing and fruiting of mushroom, its choice however depends on how readily available and their cost[71].

Numerous studies have been carried out on the use of various substrates for mushroom cultivation including; rice straw, corn cob, leaves of plants, sawdust, wheat bran, sugarcane bagasse, palm oil waste, wheat straw[72].

2.6.4 Choice of Oyster Mushroom

Oyster mushroom is a widely cultivated edible mushroom, first being *Agaricus bisporus*[73] belonging to the family *Pleurotaceae,* Mushroom belonging to this genus *Pleurotus* are edible fungi having high importance commercially[74]. Oyster mushrooms can grow and perform best at temperatures range of between 20°C and 30°C and a relative humidity of 55 - 70%.

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Pleurotus species are rich in protein, minerals, vitamins and chemical compounds. Mushroom is an excellent food source to alleviate malnutrition, fight against diabetes, ulcer and various diseases.

Mushroom farming is an eco-friendly and profitable agricultural business[75]. It is an economically viable biological process of converting plant waste and residue to substrate which has the same function as soil in plant production[76]. These substrates include: cereal straw, sawdust, corn cob, sugar cane straw and more[76].

Recent researches revealed that mushroom mycelium is effective in the myco-restoration of spoilt environments by using the mycelia to filter water, myco-forestry where mycelia is used to restore spoilt forests, myco-remediation which involves the use of mycelia to remove toxic waste and myco-pesticides involving the use of mycelia to control pests. These methods will leave no damage on ecosystem after fungal implementation[77].

Due to their absence of vascular tissue and chlorophyll, fungi are classed as eukaryotic organisms and belong to their kingdom[78]. They exist by breaking down the organic matter in dead organisms and feeding on them, they decompose and recycle the nutrients left behind by decayed plants[70]. Animals and plants are symbiotic with other fungi. The chitin-containing cell wall of fungi, which resembles the exoskeleton of insects and arachnids, is one characteristic that sets them apart. Fungi include unicellular yeasts that spread by budding to moulds that generate hyphae, which are multicellular filaments that are frequently generated in specialized structures called fruiting bodies that form spores.

Hearing the word "fungi," one might instantly picture rotten food in the refrigerator or mushrooms on pizza. However, fungi are present everywhere and have a significant impact on human lives, from aiding plants and causing plant infections to producing tasty mushrooms and industrially important goods as well as contributing to human illnesses. Numerous fungi are harmful because they cause a wide range of plant, animal and human

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diseases[79]. On the other hand, the list of beneficial fungi is extensive and continues to expand rapidly. For thousands of years, people have utilized edible fungi to prepare food and drink, various industries utilize fungi to produce chemical compound including vitamins, hormones, organic acids and antibiotics[80]. In the laboratory, fungi showed the ability to investigate various issues relating to genetics, mineral nutrition, metabolic pathways and more. However, their ability to recycle carbon and other vital components of the ecosystem is still being argued upon by researchers and their contributions[81]. Due to their heterotrophic nature, all fungi obtain their energy by breaking down the dead organic matter into simple molecules that can benefit the ecosystem thus making many good scavengers[58,70].

The systematic taxonomy and categorization of fungi are typically the first things that mycologists study after that comes the physiology, ecology, disease, evolution, genetics and molecular biology of fungi.

2.6.5 The Fungi Hypha

There are 11 distinct groups, 7 phyla and 4 subphyla of the polyphyletic Zygomycota that has varying genome and life cycles which make up the kingdom fungi being a part of the domain Eukarya. There are evidences showing that fungi had been in existence for long indicating their ancient ancestry. Fungi and animals are closely related than many other eukaryotic creatures based on recent discoveries[71]. Fungi are generally described as eukaryotes, they lack chlorophyl which makes them heterotrophic in nature with these characteristics; they are uninucleate or multinucleate, they have high rate of nutrient absorption and having cell wall made up of chitin . Fungi is made up of protein, carbohydrates, vitamins , essential minerals and water (69–90 %). There are three major fungal groups namely; mushroom, yeasts and moulds.[82].

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Depending on the predominant growth conditions, some fungi may combine the structure of unicellular yeast and hyphae with multicellular filaments[79].

2.6.6 Characteristics of Fungi

The following are the main traits of fungi that set them apart from the kingdoms of plants, animals and others:

1. The fungus is eukaryotic.
2. They are classified as non-vascular organisms because they have no specialized tissues for transportation.[83].
3. Majority reproduce through spores which could be dispersed by insects and wind.
4. Both sexual and asexual spores may be formed based on the specie and the surrounding circumstances[83.]
5. Most fungi are not motile but with the exception of few such as chytrids having a motile phase.
6. Although the generations may differ from those of plants, sexually reproducing fungi also have an alternating generation cycle[83].
7. The vegetative body of fungi could be unicellular or multicellular made up of hyphae.
8. The structure of fungal cell wall is similar to plants cell wall structure but there is difference in their chemical composition.
9. The secondary wall of most plant contains lignin.
10. Fungi has similar cytoplasmic ultrastructure to that of plant cell with the difference organelles and their structures.
11. Fungi are heterotrophic in nature, they could not manufacture their own food through photosynthesis, they feed on dead organic material[84].

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12. Plants store their food as starch while fungi store its food as glycogen.
13. Cholesterol is found in mammalian cell membranes while fungal cell has ergosterol.
14. Fungi has a different biosynthesis pathway, the protein formed during nuclear division is not the same with that in other organisms[84].

2.6.7 Uses of Fungi

The kingdom fungi include a number of species with diverse forms and uses. As symbionts of plant matter, they are present in all habitats and contribute significantly to the excellent functioning of the ecosystem[85]. Various industries use fungi to produce food, drinks and drugs. They have recently received a lot of attention for their use in agriculture, environmental protection and various industrial applications[85].

1. They are useful in the food manufacturing industries in fermentation process (baking , wine production, beer production)
2. Fungi are used in different ways for different purposes which includes the production of various enzymes such as pectinase, cellulase, lipases, proteinases, amylases, invertase, chitinases, ligninase.
3. In the scientific field (as research model organisms), the pharmaceutical industries, fungi are useful in production of antibiotics, anticancer medications and production of drugs to lower cholesterol level of the body.
4. In the environment, we have fungi capable of degrading hydrocarbon, bioremediation and myco-filtration of the envronment[86].
5. Fungi rich in protein can increase soil fertility leading to increased crop productivity, decrease in the usage of pesticides, fertilizers, herbicides and support sustainable farming methods[87].

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6. They are useful in researching metagenomics, genomics and proteomics to identify the biomolecules from fungi for use in pharmaceutical and agricultural applications[85].

2.6.8 Importance of Fungi in Different Sectors

The kingdom of creatures known as fungi has species that can be found in almost every type of ecosystem. They appear in a variety of morphologies and are free-living, symbiotic, unicellular or multicellular creatures[85].

1. They are primarily recognized for their crucial functions in ecology as symbionts, decomposers and they can be found in practically every sort of environment, from soil to water[58].
2. Fungi have been in use for ages in culinary and medicinal applications.
3. Fungi have recently become an important resource in contemporary biotechnology with a wide range of uses in many industries and a sustainable potential[80].
4. Micro fungi such as moulds and yeasts, macro fungi such as mushroom come in a variety of sizes. The micro-sized fungi which include species like *Penicillium, Aspergillus* and *Saccharomyces* synthesize metabolites and enzymes while the macro-sized fungi are typically employed as food or supplements for human use[88]. Fungi are regarded as one of the mainstays of contemporary biotechnology because of their capacities[80.]
5. Fungi is of great value in biotechnology according to projection, it will be well accepted and develop dramatically for essential industrial operations; in producing vitamins, enzymes, pigments and more. Additionally, they produce a variety of dietary colours including melanin (*Aspergillus species*), anthraquinones

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(*Paecilomyces farinosus*), benzoquinone (*Penicillium europium*), and β-carotene (*Blackeslea trispora*).

6. Fungi serves as the best option for producing a variety of goods and support the goal of creating more environmentally friendly manufacturing practices[80].
7. Around the world, fungi were utilized to make a variety of foods including bread, cheese, wine and fermented foods before we were able to identify the different species and comprehend what they were. Today, goods prepared with fungi typically those that come after fermentation—represent a sizable portion of global cuisine[88].

2.7 Overview of Mushroom

The phyla *Ascomycota* and *Basidiomycota* also comprise mushrooms. This taxonomy is based on a consensus. Also known as "fruits of fungus," mushrooms are a variety of filamentous *achlorophyllous*, spore-bearing, umbrella-shaped, fleshy to leathery fungal fruit bodies (sporophores) that are produced under particular nutritional, temperature and humidity conditions[89]. They can be either epigeal (found above ground) or hypogeal (found below ground) and they can feed parasitically, saprophytically or symbiotically[70].

In the past, people have hunted for edible mushrooms and utilized them for both culinary and therapeutic purposes. Nonetheless, many toxic mushrooms are still eaten, despite macro fungi being the longest-studied creatures. According to conservative estimates, the number of species of macro fungi on Earth is between 110,000 and 140,000, and only 16–41 % of these are thought to be known. There are currently 99 countries with a total of 2006 safe edible mushroom species that are considered edible to humans. Furthermore, only 30 of the approximately 90 kinds of mushrooms that can be grown for food or

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medicine are commercially grown and consumed globally. Mushrooms are superfood with numerous applications in nutritional supplements[88].

Mushrooms has a high fiber content, protein, vitamins, minerals and reduced fat content. Since they are as nutritious as a number of vegetables, mushrooms are regarded as an alternative to meat[87,88]. Mushroom farming is a great technique to recycle agricultural waste and give vegetarians better nutrition and health advantages by using waste to grow fungi that are high in protein and nutrients[19,24].

Consumption of mushrooms has increased as a result of growing awareness of their health benefits and recent recognition of them as a functional food[90]. Numerous mushroom cellular constituents and secondary metabolites have been shown to affect the immune system; as a result, they may be used to cure illnesses[90]. The market for fungal metabolites has grown due to the low cost of mushroom reproduction and high product output. In the food industry, mushrooms are acknowledged as a broad category of fungi that can be used to make functional meals with a significant amount of bioactive chemicals, as well as nutraceuticals, myco-therapeutics and cosmeceuticals[88].

2.7.1 Nutritional Components of Mushroom

Mushroom is rich protein, high fiber content and low fat and other useful components like phenolics, they are now acknowledged as important source of protein with high quality[91]. Because of their complete essential amino acids and great nutritional value, mushroom proteins have recently acquired flavor in the food sector[91]. Mushroom proteins often provide a full necessary amino acid profile, meeting nutritional requirements and offering some financial benefits when compared to animal protein and protein from plant sources[91]. Numerous mushrooms can quickly produce large yields when grown on agricultural wastes. Branched-chain amino acids (BCAAs) is present in mushroom protein with a high

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temperature and pH stability brought about variation in their digestibility. Mushrooms having high fiber content can bring about the release of reducing sugar during the process of digestion which might result in a Maillard reaction, reduction in lysine, tryptophan and methionine[84]. Researchers found out that the phenolics, phytates, phenolics and tannin present in mushroom hinders the effective functioning of some enzymes such as the digestive enzyme, pepsin, amylase and pancreatin[91]. Mushroom protein has the potential of improving human nutrition as revealed by the fruiting bodies frequently eaten is a source of protein while these proteins produce amino acids which helps in bodily functions. Current research found mushroom protein as strong antiviral, anticancer and antioxidant properties[90,91].

A good mushroom is an important source of fatty acids primarily linoleic acid and majority of the edible mushrooms are composed of carbohydrates. Also trace elements such as iron, copper, molybdenum, iron, selenium; macronutrients such as potassium, salt, calcium magnesium essential for human body are present in a healthy mushroom[92]. Mushroom has high level of vitamin B1 (Thiamine), B2 (Riboflavin), B3 (Niacin) and B5 (Pantothenic acid). Mushrooms can produce more vitamin D when exposed to sun ultraviolet radiation although mushrooms do have carotenoids which are chemicals that are a source of vitamin A and a trace amount of vitamin C[93]. Food high in dietary fiber includes mushrooms. *F. velutipes* has the greatest nutritional fiber content of any common mushroom with 137.2 g/kg[92]. Their nutritional profile may vary depending on the species, maturity and growing conditions[92]. Below is a general overview of the nutrients found in commonly consumed edible mushrooms per 100 grams (fresh weight).

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Table 2.4: Nutrient Composition of Mushroom

Nutrient	Quantity (per 100g)	Remarks
Calories	22 kcal	Low in energy
Protein	3.1 g	Contains all essential amino acids
Carbohydrates	3.3 g	Includes dietary fiber
Diet Fiber	1.0 g	Supports digestive health
Fat	0.3 g	Very low-fat content
Vitamin D	0.2–2.5 µg	Varies with UV exposure
Vitamin B2	0.4 mg	Supports energy metabolism
Vitamin B3	3.6 mg	Important for skin and nerves
Potassium	318 mg	Regulates blood pressure
Phosphorus	86 mg	Essential for bones and teeth
Iron	1.0 mg	Supports oxygen transport
Zinc	0.5 mg	Helps immune function

Source[62]

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2.7.2 Morphology of Mushroom

The mycelium, also known as the vegetative body is one of the two main components of the mushroom body. It is made up of several branching septate (segmented) hyphae that resemble threads and grow in the substrate[95]. It is still concealed beneath the ground having the basic and structural component of multicellular fungi which is the hypha, a single filament that resembles a thread. Both the fruiting body (reproductive body) and the vegetative body known as the mycelium are formed by the network of hyphae[71]. The mycelium aids in the mushroom's attachment to the substrate and in the uptake of soluble nutrients from it. There are two kinds of mycelium:

1. **Monokaryotic Primary Mycelia**

A network of uninucleate septate hyphae makes them up. They are transient and use plasmogamy or somatogamy to produce long-lived secondary mycelia.

2. **Dikaryotic Secondary Mycelia**

They yield what are known as basidiocarps or developed mushrooms, which are aerial fruiting structures. Another name for a basidiocarp is a spawn, the reproductive or fruiting body.

The following components make up the fruiting body or basidiocarp:

a) Pileus

Another name for it is a roof or cap that shield the gills and has an umbrella or parasol-like form. The pileus can have scales on its upper surface and be either white or brilliant and colourful.

b) Lamellae or gills

There are rows of vertical plates under the surface of the pileus. A fruiting body's reproductive organ produces brown reproductive spores known as basidiospores[95].

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c) Stipe or Stalk

It is a fleshy structure that supports the heavy pileus in the shape of an umbrella and functions as a stem.

d) The Annulus

It is a structure that resembles a membrane ring that is at the upper side where the stripe is directly below pileus.

e) Volva

At the base of the stipe is a structure that resembles a cup, the veil's remnant is volva. A young basidiocarp is covered by a very thin membrane called the veil of velum. The mushroom's velum ruptures when it reaches maturity. It leaves behind its residue in the form of an annulus (near the stalk's pileus) and volva (near the stalk's base)[95].

Three separate areas can be seen in a vertical segment of the pileus via the gills:

f) Trama

The innermost portion that is spongy in nature of the gill is trama which is formed by elongated fungi as a result of their coming together.

g) The Sub-hymenum

This is a compact layer of small hyphae branches that is located outside the trama.

h) The Hymenium

It is made up of two kinds of cells and is the outermost fertile part of a gill.

i) Basidia

They are bigger, bi-nucleated cells that resemble clubs. These cells are fertile and subsequently give rise to basidiospores.

j) Paraphyses

They are slimmer and shorter but they are also bi-nucleated. They cannot produce basidiospores because they are sterile cells.

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2.7.3 Bioconversion of Lignocellulosic Waste

The only currently available cost-effective biotechnology process for recycling lignocellulose organic waste that produces both food high in protein and lowers pollution levels is the cultivation of saprophytic edible mushrooms[19,24]. An excellent illustration of how low-value waste generated mainly by agricultural practices which includes; plant production, animal production and processing industries may transform into valuable products that benefits humanity is the production of edible mushrooms[19]. For example, edible oyster mushrooms have a great flavour and taste making them lucrative and a source of revenue in agribusiness. It facilitates the transformation of lignocellulosic waste into food that contains high-quality protein[1,25].

Turkey is the country with the highest percentage of mushroom production and *Agaricus bisporus* the most widely produced in large numbers using various agricultural wastes as the substrate for its cultivation[16].

A number of benefits make mushroom cultivation achieve a great fit in sustaining agricultural practices including the use of agricultural waste as substrate in producing valuable products; production of nutrient-rich protein and the biodegraded substrate serving as feed to ruminants.

Mushroom cultivated on various type of substrate such as; sugarcane bagasse, corn cob, rice straw, sawdust and numerous others are capable of producing wide range of lignocellulolytic enzymes[60]. Sawdust is one of the substrates used in a variety of works to grow mushrooms which serves as a source of income generation[96].

Although there are several edible mushroom species in Nigeria, majority of these native mushroom species are endangered, the production of mushrooms in natural forests is in jeopardy however, it is known that mushrooms naturally inhabit specialized ecological niches within tropical forests but most habitats of mushrooms are continuously being

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destroyed for agricultural purpose. Natural forests that may serve as habitats for mushrooms and other non-timber forest products were severely destroyed when exotic cash crops like cocoa, rubber, cotton, groundnuts and oil palm were introduced into traditional farming in the 1950s[63]. The fruiting season occurs during cool and humid conditions this makes it possible to artificially grow mushrooms in regulated or semi-controlled environments[63].

In order to address the worldwide food crisis and the undervaluation of mushroom particularly in developing nations, they are currently cultivated on a large scale to satisfy the dietary requirements of the populace. Accordingly, mushrooms can be seen as a beneficial food supplement and are particularly helpful in a diet that is primarily vegetarian[91].

2.8 Positive Effect of Mushroom on Health

1. The chemical composition content, vitamins and minerals in mushroom helps in getting rid of free radicals from the body[90].
2. The antioxidant present in mushroom prevents the malignant growth of cancer.
3. Vitamin D present in mushroom prevents cancer development.
4. Mushroom has potassium which is an element that helps to reduce cardiovascular diseases, hypertension and monitoring blood pressure[94].
5. The folic acid in mushroom keeps the pregnant woman and the baby in a healthy state
6. Mushrooms serves as alternative source of protein instead of the red meat.[90].
7. Mushrooms generally upgrades nutrition and diet quality[91].
8. The long-chain polysaccharide in mushroom serves as immune system enhancer.

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Table 2.5: Identification of Edible and Poisonous Mushrooms

Characters	Edible Mushroom	Poisonous Mushroom
Color	White or grey	Ornamental
Scales	Absent	Present
Smell	Pleasant smell	Unpleasant smell
Using a silver spoon	No colour change in the spoon	The spoon colour changes to black
Cooking with onion	No onion colour change	The onion colour changes to black
Presence of latex	Absent	Present

Source[63]

Examples of edible mushrooms include:

1. Button mushrooms
2. Oyster mushrooms
3. Paddy Straw Mushroom
4. *Calocybe indica*, or milky mushroom
5. *Lentinula edodes*, or black/black forat mushrooms
6. *Flammula velutipes*, often known as the winter mushroom or velvet stem mushroom.

2.9 Biodegradation

This is a natural process of breaking down complex compounds into simpler ones by micro organisms[43]. Saprophytic fungi are effective in degrading these complex compounds because of their inability to manufacture their own food, they depend on

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dead organic matters for their food. Biodegradation using edible fungi offers a sustainable solution by converting agricultural wastes into valuable products such as biofertilizers, animal feed and even food sources[14,19]. Edible fungi such as *Pleurotus ostreatus*, *Lentinula edodes* and *Agaricus bisporus*, play a crucial role in breaking down complex organic materials[60]. The process involves:

1. Enzymatic Action: Fungi secrete hydrolytic enzymes such as cellulases, hemicellulase and ligninase which degrade lignocellulosic biomass[60].
2. Mycelial Growth: The fungal mycelium penetrates the waste material, facilitating decomposition[58].
3. Bioconversion: The degraded biomass is transformed into simpler compounds enhancing soil fertility and reducing waste accumulation[26,99].

2.9.1 Environmental and Economic Benefits of Biodegradation

1. Waste Reduction: Agricultural residues such as rice husks, maize cobs, sugarcane bagasse are efficiently decomposed[58,65].
2. Biofuel Production: Fungal biodegradation aids in the conversion of lignocellulosic biomass into bioethanol[22,65].
3. Soil Enrichment: The process enhances soil health by increasing organic matter content.
4. Sustainable Agriculture: Farmers can utilize fungal-treated waste as compost thereby reducing reliance on chemical fertilizers[26,28].

2.10 Fungal Biodegradation

Fungal Biodegradation refers to the process by which fungi break down complex organic materials including pollutants and waste, into simpler, non-toxic compounds[65]. This

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process plays a critical role in natural ecosystems and is increasingly used in environmental cleanup (bioremediation), waste management and industrial processes[64,65].

2.10.1 Steps of Fungal Biodegradation

Fungi secrete powerful extracellular enzymes and acids that degrade tough organic materials[60]. The key mechanisms include:

1. Enzymatic Degradation: Ligninase, Laccases, Manganese, Peroxidase are enzymes produced by fungi to break down lignin and complex aromatics, Cellulases for breaking down cellulose, Proteases, lipases, and amylases for breaking down proteins, fats and starches[60].
2. Mycelial Growth: Fungal hyphae penetrate materials physically disrupting them and facilitating enzymatic action[77].
3. Metabolism: After fungal metabolism on the resulting simpler compounds are converted to biomass, water and carbon dioxide.

2.10.2 Factors Affecting Fungal Degradation

There are various biotic and abiotic factors affecting the breakdown of complex materials in agricultural wastes into simple compounds[97] . These factors are important in the fungal degradation in environmental and industrial application such as in biofuel production, waste management and bioremediation. These factors include:

The Fungal Strain Involved: Different fungal species has varying abilities in enzymatic degradation. White rot fungi are known to be effective in degrading the lignocellulosic content of the agricultural wastes[98] .

The Characteristics of the Substrate: This depends on the composition of the substrate, physical characteristics in terms of porosity, ease of enzyme penetration[99].

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Environmental Conditions: These include;

i. Temperature: Majority of fungi are mesophilic in nature. They operate between the temperature range of between 20-30 ^{o}C though some operate at higher temperatures as well[100].

ii. pH: This depends on the specie of the fungi, 4.0 and 6.5 is majorly the pH for fungal degradation.

iii. Oxygen: The oxidative enzymes function perfectly in the presence of oxygen, as fungi are known to be aerobic.

iv. Enzyme Activities: During enzyme production, the quantity and the specificity affects the rate and extent of degradation[101] .

v. The Available Nutrient: Nutrients such as nitrogen, phosphorus and trace metals can inhibit fungal growths and metabolism[102].

vi. Presence of Inhibitory Compounds: Compounds that are antifungal or antimicrobial in nature present in the substrate can inhibit fungal growth and affect enzymatic actions[103].

vii. Interaction and Competition: Fungal competition in the natural environment can influence rate of degradation. Microorganisms that are antagonists to frugal degradation will suppress fungal activities while the supportive ones will assist in the breakdown of complex compounds[104].

viii. The Time of Incubation and the Duration Affects Fungal Degradation: Lignin is slow in degradation while cellulose and hemicellulose are faster[105].

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2.10.3 Limitations of Fungal Degradation

Inability to Tolerate Nutrient Deficiency or Excess: Lignocellulolytic enzyme production can be suppressed when nitrogen is deficient or in excess. Substrates with nitrogen variability affect fungal metabolism[106].

Incomplete Degradation: Fungi might prefer to degrade cellulose and hemicellulose faster leaving behind lignin and the process of mineralization completely is not common, it will require additional microbial action[107].

Scalability: Fungal degradation is effective in the laboratory or in small scale. To scale up to industrial level is often hindered by:

1. The high cost of operation.
2. Environmental control inconsistency.
3. Inability to maintain uniform fungal colonization[108].

Variability in Substrate: There is variation in the composition, moisture and composition of agricultural wastes and these affects the ability of the fungi to reproduce. It makes difficult the process of standardization and optimization[109].

2.10.4 Overcoming the Limitations of Fungal Degradation

1. Ensuring the optimization of environmental conditions in which controlled bioreactions can be employed to maintain an ideal temperature, pH, Oxygen and moisture. Also, solid state fermentation process can be introduced which is effective in degradation of lignocellulose content of wastes[78,108].

2. Culturing of organisms together such as co-culturing fungi with bacteria, fungi with protozoans and more. This improves substrate utilization and complete mineralization.

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3. Fungi can be engineered genetically or metabolically to produce key enzymes, to increase temperature range and improves tolerance to toxic compounds[108,109].

4. Selection of strains that are robust to ensure long term culturing.

5. Addition of nutrient supplements can increase enzymes production.

6. Use of biochar, adsorbent materials to remove toxic materials[76,78,100] or heavy metals in substrates.

2.10.5 Applications of Fungal Biodegradation

1. Bioremediation: Degrading pollutants which includes; petroleum hydrocarbons, pesticides, dyes, heavy metals and PCBs can be broken down by white-rot fungi (e.g., *Phanerochaete chrysosporium*) which is very effective at breaking down persistent organic pollutants[76].
2. Waste Treatment: Composting agricultural and food waste. Myco-remediation: using fungi to clean up contaminated soil and water.
3. Plastic Biodegradation: Some fungi (e.g., *Aspergillus, Penicillium, Fusarium*) can partially degrade plastics like polyurethane, PET, and polyethylene[65].

2.10.6 Mechanism of Fungal Degradation

Fungal degradation can be carried out using various substrates. The enzymatic action on the substrate breaks down the lignocellulosic content in the substrate which is complex in nature and converting them to simpler structures for animal digestiblty[70.] This is a productive way of using the build-up in agricultural wastes to produce valuable products for human and animal use. Mushroom cultivation using edible fungi is in line with microbial science, solid state fermentation approach and environmental science to

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transform agricultural, industrial and domestic wastes to nutritional and valuable products[25].

2.11 Cultivation of Mushroom

Mushroom cultivation biologically is a new biotechnology process of reducing, re-use and recycling of agricultural wastes rich in lignocellulosic materials resulting the production essential and valuable products also reducing environmental pollution[14,16,19]. There are various substrates used in cultivating mushroom such as corn cob, sugarcane bagasse, wheat bran, rice straw and others[22].

2.11.1 Steps in Mushroom Cultivation

1. Composting: This is the first step in the process of mushroom cultivation after the gathering of the materials to use. It involves the preparation of the substrates (cleaning, shredding), mixing with water and other needed materials then fully wrapped in a big cellophane bag to moisten it (as in case of corn cob).
2. Bagging: After the moistening of the substrate, it will be distributed into smaller plastic bags, tightly covered.
3. Sterilization: The bags were moved into the autoclave and sterilized at 121 ^{0} C for 5 hours to kill all the contaminants in the substrate.
4. Inoculation: The fungal spawn is then inoculated into the substrate in the inoculating chamber and kept in the dark room to monitor its mycelial growth.

After the mycelial ramification, the growth was terminated to use the substrate for the production of animal feed and the bags for growing mushroom moved to the fruiting room for premodial initiation to occur and fully grown mushroom germination.

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Mushroom cultivation is an economically viable agricultural business. All over the world, there are more than 100 species of edible fungi but unfortunately, mushroom does not have wide recognition and acceptance because they are regarded as being poisonous but with the introduction of biologically cultivated mushrooms which is free from contamination and safe for human consumption, the orientation is gradually changing[79].

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Chapter Three

Materials and Methods

3.1 Sample Collection

Sweetcorn cobs were collected from Agricwas farm and agro-business consulting firm at Aba-oke village, Lagelu local government, Ibadan, Oyo state, Nigeria. Cobs were sundried to reduce its moisture content and shredded.

3.2 Collection of Mushroom Spawn

Pleurotus pulmonaris, Pleurotus ostreatus, and Pleurotus citrinopileatus were obtained from the mushroom unit National Institute for Horticultural Research (NIHORT), Jericho, Idi-Ishin, Ibadan, Nigeria.

3.3 Materials and Equipment

Sweetcorn cob, Rice bran, Calcium carbonate, Substrate bags, Inoculating loop, Mushroom spawn, Water, Weighing balance, Face mask, Gloves, Paper tape, Measuring tape, Autoclave, Gas, Bucket, Ethanol, Boiling tubes, Cotton wool, Foil paper

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3.4 Method

3.4.1 Preparation of Substrate

The sweet corn cobs were sundried to reduce its moisture content, chopped into smaller sizes and taken to NIHORT at Jericho.

3.4.2 Composting

1. 20 kg of the dried corn cob and 5 kg of rice bran were weighed.
2. 0.20 kg of calcium carbonate
3. Mixed with 20 L of water to moisten the corn cob
4. The mixed substrate was wrapped in a large plastic bag for 3 days.

The rice bran was added to;

1. Allow microbial metabolism
2. Add nitrogen protein to the substrate
3. Create crepsis between the substrate for easy mycelia growth.

Calcium carbonate;

1. To stabilize the pH of the substrate
2. Increase phosphorus availability
3. Improve root system performance

On the third day, the substrates were packed into a polythene bag of size 25 x 15 cm, weighing 500 g, perfectly packed, bags closed up using PVC (Poly Vinyl Chloride) tube which is resistant to heat. The opening at the center of the PVC was covered with cotton wool through which the spawn was inoculated later.

Also, 5 g of substrate was packed into 15 boiling tubes, 5 each for one spawn, to monitor the rate of mycelial ramification.

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3.4.3 Sterilization

The bags and the test tubes were packed into the autoclave, in which an improvised autoclave (metal drum over naked flame) was used to sterilize at 121 °C for 5 hours.

3.4.4 Inoculation

The bags and the tubes were packed to the inoculating room. A 20 g of the inoculum of the three mushrooms to use (*Pleurotus pulmonarius, Pleurotus ostraetus, and Pleurotus ctrnopileatus*) were introduced into the substrate bags and 2 g of the inoculum into the boiling tubes with five replicates per treatment in the inoculating chamber.

3.4.5 Incubation

The bags were packed in the dark room to be incubated for 3 weeks from the day of spawning. The mycelial growth was monitored every 3 days for 3 weeks. Vertical mycelial extension rate was taken trice in a week. After 3 weeks of degradation by the fungi, both the substrates in the bags and the boiling tubes were fully ramified and growth terminated, 2 bags each from the 5 replicates for further analysis were kept and the remaining bags were packed to the fruiting room where mushroom would grow on them. After full colonization of the bags, they were weighed using an electronic weighing digital scale then moved to the fruiting room where the primodial initiation of the fruiting bodies and fully grown mushroom emerge and are harvested manually by twisting the base of fruiting body gently, avoiding remnants of its part on the bags to prevent spoilage. The 2 bags reserved for analysis from each replicate were sun dried and milled for the chemical composition analysis, mineral and vitamin analysis.

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3.5 Data Analysis

Data obtained were analyzed using one-way ANOVA and Excel Spreadsheet Statistical Package by the AOAC official method in a complete randomized timeline.

3.6 Chemical Composition Analysis of Biodegraded Sweetcorn Cob

The chemical composition analyses were carried out on 9 components in the samples determining nutrient enrichment in the substrate. The components analyzed includes; Ash, Crude protein, Ether Extract, Crude fiber, Neutral detergent fiber, Acid detergent fiber, Lignin, Cellulose, Hemicellulose.

3.6.1 Method of Analysis

Samples chemically analyzed in accordance to the official methods of described by the Association of Official Analytical Chemists (AOAC 18TH EDITION, 2). The analyses were in triplicate.

3.6.2 Dry Matter and Moisture Determination

1. Apparatus: Crucibles, balance, oven, desiccator and oven.
2. Reagents: Grease, silica gel.
3. Procedure: Two grams of the sample (W_1) was weighed into a previously weighed dry crucible (W_2). The crucible plus sample added (W_3) was then transferred into the oven at 100 ºC for drying to a constant weight for 24 hours. The crucible plus sample was removed from the oven and transferred to a desiccator, cooled for ten minutes and weighed (W_4) after the expiration of the 24 hours[1].

$$\%\ Moisture = \frac{W_3 - W_4}{W_1 - W_2} * \frac{100}{1}$$

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$$\% \, Dry \, matter = \frac{W_4 - W_2}{W_1 - W_2} * \frac{100}{1}$$

OR

$$Dry \, Matter = 100 - Moisture \, content$$

3.6.3 Crude Protein Determination

The routine semi-micro Kjeldahl procedure/technique was used to determine the crude protein content in the sample. The techniques involved in the analysis include; digestion, distillation and titration.

1. Apparatus: analytical balance, 50 mL burette, digestion tubes, digestion block heaters, 5 mL Pipette, 10 mL pipette, fume cupboard, 10 mL measuring cylinder and 100 mL beakers.
2. Reagents: Conc.H_2SO_4, 40 % (W/V) NaOH, 0.01M NHCL, 2 % boric acid solution, Kjeldahl catalyst tablet, methyl red – bromocresol green mixed indicator[2].

Digestion

A 0.5g of finely ground dried sample was weighed carefully into each of the Kjeldahl digestion tubes (record as W_o). 10 mL of concentrated H_2SO_4 was added to the digestion tubes alongside a Kjeldahl catalyst tablet of about 1 g catalyst mixture. The tubes were heated in a fume cupboard for 4 hours, gently at first, then strongly until the digest became clear. The digest was cooled down and carefully transferred into a 100 mL volumetric flask, the digestion tube was thoroughly rinsed and filled with distilled water[2].

Distillation

Distillation was carried out using the Markham Distillation Apparatus, it allows volatile substances such as ammonia to be steam distilled with the complete collection of the distillate. The apparatus was steamed out for about ten minutes, the steam generator removed from the heat source to allow the developing vacuum to remove condensed

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water. The steam generator is then placed on the heat source (i.e., heating mantle), and each component of the apparatus is fixed up appropriately.

Procedure: A 5 mL portion of the digest obtained was pipetted into a Markham Distillation Apparatus containing approximately 5 mL of 40 % (W/V) NaOH. The mixture was steam-distilled for 2 minutes into a 50 mL conical flask containing 10 mL of 2 % Boric acid plus a few drops of mixed indicator placed at the receiving tip of the condenser. The solution in the conical flask changes colour from red to green revealing that all the ammonia liberated has been trapped[2].

Titration

The solution obtained (green colour) was then titrated with 0.01 N HCL contained in a 50 mL burette. At the equivalent point or end point, the green colour turned pink which shows that all the Nitrogen trapped as Ammonium Borate [$(NH_4)_2BO_3$] has been removed as Ammonium chloride (NH_4CL). The percentage nitrogen content is calculated as;

$$\% N = \frac{(V_t - V_b) * N_{acid} * 14.01}{W} * \frac{100}{1}$$

Where;

V_t = volume of acid used in titration (mL)

V_b = blank titration volume (mL)

N_{acid} = normality of HCl

14.01 = atomic weight of Nitrogen (g/mol)

W = weight of sample (g)

The crude protein content is determined by multiplying the percentage nitrogen by a constant factor of 6.25, i.e.

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$$\% CP = \% N * 6.25$$

3.6.4 Ether Extract or Crude Fat Determination

1. Apparatus: Soxhlet apparatus and accessories, desiccator, analytical balance and oven.
2. Reagents: Petroleum spirit or Ether (40 ºC – 60 ºC b.pt).
3. Determination: 1 gm of each dried sample was weighed into fat fat-free extraction thimble and pugged gently with cotton wool. The thimble was placed in the extractor, fitted up with a reflux condenser and a 250 mL Soxhlet flask, which had been previously dried in the oven, cooled in the desiccator and weighed. The Soxhlet flask then filled to $^3/_4$ of its volume with petroleum ether (b.pt. 40 ºC – 60 ºC) and the Soxhlet flask. The extractor and condenser set was placed on the heater. The heater was put on for six hours while running water constantly on it from the tap for the condensation of ether vapour. The set was constantly watched for ether leaks and the heat source was adjusted appropriately so that the ether can boil gently. The Ether was left to siphon over several times, at least 10 – 12 times, until it was short of siphoning. Then, any ether content of the extractor was carefully drained into the ether stock bottle. The thimble containing the sample was then removed and dried on a clock glass on the bench top. The flask, the extractor and the condenser were replaced, the distillation continued until the flask was fully and practically dry. The flask containing the fat or oil was detached, its exterior cleaned properly and dried to a constant weight in the oven. If the initial weight of the dry Soxhlet flask is Wo and the final weight of oven oven-dried flask + oil/fat is W_1, the percentage fat/oil is obtained by the formula[3];

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$$\% \, Crude \, fat = \frac{W_1 - W_o}{W_{sample}} * \frac{100}{1}$$

3.6.5 Ash Determination

1. Apparatus: Analytical balance, porcelain crucibles, desiccator and a furnace.
2. Procedure: A 1.0 gm of the sample was weighed (W_1) into a clean, dry and pre-weighed porcelain crucible (W_2) which was placed into the muffle furnace set at 520 ºC and left there for about 4 hours. During this time, the sample had turned to white ash. The crucible and its content then cooled to about 100 ºC in air, then to room temperature in a desiccator and weighed (W_3)[4]. Percentage ash content was calculated using;

$$\% \, Ash \, content = \frac{W_3 - W_2}{W_1} * \frac{100}{1}$$

3.6.6 Crude Fiber Determination

1. Apparatus: Crucibles, heating mantle, sieve cloth, furnace, fiber flask, funnel, analytical weighing balance and a desiccator.
2. Reagents: Acetone, 0.255N H_2SO_4 and 0.313N NaOH .
3. Procedure: A 1 gm of sample at different stages of fungal degradation was placed into the fiber flask. Then, 100 mL of 0.255 N H_2SO_4 was added to the flask. The mixture was then brought to a gentle boil at 100 ºC for about 30 minutes. This mixture was then filtered through a pre-weighed fiber sieve cloth and the residue was kept while the filtrate was washed away. Then, the residue was immediately transferred back to the flask to which 100 mL of (0.313N NaOH) was added and again brought to boil at 100 ºC for about an hour. The mixture was filtered through a fiber sieve cloth and washed thoroughly with hot water then with 10 mL

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acetone before it was transferred to the crucible. The crucible containing the residue was oven-dried at 105 ºC overnight, cooled in a desiccator and weighed. The crucible content consists of crude fiber and some residual ash. To remove the ash content, the crucible is placed in muffle furnace at 550 °C for 4 hours after which it is cooled again in a desiccator and re-weighed[5]. The percentage crude fiber content was determined as the loss in weight due to ashing;

$$\%\ Crude\ fibre = \frac{W_{residue} - W_{ash}}{W_{sample}} * \frac{100}{1}$$

3.7 Analysis of Fiber Fraction

3.7.1 Neutral Detergent Fiber (NDF) Determination

1. Reagents:

Neutral detergent solution

6.81 g of Sodium borate decahydrate.

18.61 g of Disodium ethylenediaminetetraacetate.

30 g of Sodium lauryl sulfate neutral.

10 ml of 2-ethoxyethanol (Ethylene glycol monoethyl ether, cellosolve)

Disodium phosphate anhydrous 4.56 g

1000 ml of distilled water.

Sodium borate and disodium EDTA were poured into a beaker and dissolve with a part of distilled water while heating it, gradually add lauryl sulfate and 2-ethoxyethanol. Dissolve disodium phosphate separately in part of distilled water and continue heating until a complete solution is obtained. Mix the remaining distilled water and the two solutions under a controlled pH which must be between 6.9 and 7.1.

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2. Procedure: Dried samples were ground into fine powder and was made to pass through a 1 mm screen to ensure uniformity. One gram of the ground and sieved sample was placed in a pre-weighed Gooch crucible (recorded as W_1), was treated with 100 mL of neutral detergent solution at room temperature. The mixture was then brought to boil and refluxed by placing it on a hot plate for about an hour. The sample was then rinsed properly with hot distilled water, then with acetone to remove detergent residues and leftover solubles. The washed residue which contains only the neutral detergent fiber, was then dried at 105 ºC, cooled in a desiccator, weighed and recorded as W_2[6]. Percentage NDF can be calculated using:

$$\% NDF = \frac{W_2 - W_1}{wt.\ of\ sample} * 100$$

Where;

W_1= Weight of the empty crucible

W_2 = Weight of the crucible plus residue after drying.

% Neutral Determination Soluble (NDS) can be calculated using;

$$\% NDS = 100 - \%\ \text{NDF}$$

It was later ashed at 550 ºC for 2 hours in a muffle and allowed to cool in a desiccator in order to calculate the ash insoluble in acid detergent using the formula;

$$Ash\ insoluble = \frac{loss\ of\ ashing}{weight\ of\ sample} * 100$$

3.7.2 Acid Detergent Fiber (ADF) Determination

1. Reagents:

Acid detergent solution

A 20 g of Cetyltrimethylammonium bromide technical grade ($C_{19}H_{42}BrN$)

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Sulfuric acid 1 N (H_2SO_4, 49.04 g/l) 11 g

Dissolve tensioactive into acid and continue stirring for proper dissolution.

n-octanol ($C_8H_{18}O$) octilic alcohol.

Acetone.

2. Procedure: The sample was passed through a screen 1 mm opening to ensure uniformity and a 1 gm of it was weighed into a pre-weighed crucible (recorded as W_1). Into the crucible containing the sample, 100 mL of the acid detergent was added and the mixture was heated to boiling and gentle reflux for an hour at approximately 100 ºC. During the heating process, gentle shaking of the crucible was employed to ensure uniform exposure of the sample to the reagent. Mixture was then filtered and the residue was washed with boiling water then with acetone. The washed residue was then dried using an oven at 105 ºC for about 8 hours and was allowed to cool in the desiccator and reweighed (recorded as W_2)[7].

$$\% \, ADF = \frac{W_2 - W_1}{weight \, of \, sample} * 100$$

Where;

W_1= Weight of the empty crucible

W_2 = Weight of the crucible plus residue after drying.

3.7.3 ADL Determination (Acid Detergent Lignin)

1. Reagents:

Sulfuric Acid (H_2SO_4) 72 %: Add carefully 100 mL conc. Reagent-grade acid to 36 mL of water. Concentrated reagent-grade acid is 96 % with a sp. gr. 1.84. 72 % ADL acid should have a sp. gr. of 1.634 at 20 ºC.

Acid Detergent IV solution

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2. Procedure: The ADF procedure was used to determine the lignin content. ADF must be run eventually before ADL analysis can be done, however the ADF procedure does not have to be quantitative. The crucible with the ADF residue was placed in a beaker for support. The contents were covered with cooled (15 ºC) 72 % H_2SO_4. With a glass rod, the residue was stirred into a paste, breaking up all lumps. The glass rod was left in the crucible which was filled one-half full with acid and stirred. Refilled with 72 % H_2SO_4, it was stirred at hourly intervals as the acid drained away. Acid treatment was maintained at 20-23 ºC for 3 hours. Filtering off as much acid as possible with a vacuum, the contents were washed with boiling water until free from acid. The glass rod was rinsed and removed so as to lose no dry matter. The residue was rinsed with a volume of water and dried with a vacuum and for 24 hours in an oven at 105 ºC. The crucibles were weighed after cooling in a desiccator. The crucible was then ignited in the muffle furnace at 400 ºC for 3 hours, then cooled and weighed. It is advised not to open the muffle furnace until below 200 ºC. The crucibles were placed when still hot into a desiccator, then cooled and weighed. If the crucible is cold when removed from the furnace, dry it in an oven for 2 hours at 105 ºC before placing it in desiccators[8].

$$\% \, Lignin = \frac{(dry\,wt.\,crucible + contents\,before\,ashing) - dry\,wt.\,after\,ashing}{initial\,weight\,of\,sample}$$

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3.8 Vitamin Analysis of Sweetcorn Cob

3.8.1 Vitamin B3 (Niacin)

1. Apparatus/Reagent:

   Weighing Balance

   Niacin (Nicotinic acid)

UV-Visible Spectrophotometer

Standard Stock Solution (100ppm of Niacin): 1.23 g of niacin was dissolved in 100 mL distilled water to give 100 ppm standard stock solution.

2. Procedure

A 0.5 gm of the ground sample was weighed into a centrifuge tube and to it was added 15 mL of distilled water which was spun for an hour to completely extract the niacin present in the sample. The mixture was then filtered through a Whatman filter paper and the residue was rinsed with about 5 mL of distilled water after which the filtrate was collected and diluted with distilled water up to the 25 mL mark of the volumetric flask. A 100 ppm standard stock solution was prepared by dissolving 1.23 gm of niacin in 100 mL of distilled water. Then, 5 ppm, 10 ppm, 15 ppm, 20 ppm, 25 ppm and 30 ppm were also prepared from the standard stock solution by diluting 2.5, 5, 7.5, 10, 12.5 and 15 mL respectively in 50ml with distilled water to get the working standard. The working standard solutions were read in the UV-Visible spectrophotometer at 300 nm using distilled water as a blank. The absorbance of the solution was measured using the same apparatus and wavelength[9]. The factor amount of niacin in the sample was calculated using the formula;

$$Niacin\ (mg/100\ g\ dry\ matter) = \frac{C * V}{weight\ of\ sample} * 100$$

Where;

C = concentration of niacin from standard curve (mg/mL)

V = final volume of extract (mL)

3.8.2 Vitamin B1 (Thiamine)

1. Apparatus/Reagents:

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Weighing Balance

0.1 M HCl

1 M NaOH

UV-Visible Spectrophotometer

Thiamine Hydrochloride

Standard Stock Solution (100 ppm of Thiamine): 0.01 gm amount of pure Thiamine HCl was dissolved in distilled water in a 100 mL volumetric flask.

Working Standard and Calibration Curve

Here, 10 ppm, 20 ppm, 30 ppm, 40 ppm and 50 ppm were prepared from the standard stock solution to get the working standard.

2-Procaine hydrochloride ($2.5x10^{-2}$ M): Add 0.682 g of pure procaine HCl to distilled water, diluting it to the 100 mL mark of a volumetric flask.

Sodium nitrite solution ($2.5x10^{-2}$ M): Add 0.1725 g of $NaNO_2$ to distilled water, diluting it to the 100 mL mark of a volumetric flask.

2. Procedure

Into a centrifuge tube, a one gram of the sample was weighed and to it, was 20 mL of distilled water added and spun n a centrifuge for about 60 minutes to completely extract the vitamin contents of the sample. The mixture was then filtered through a Whatman filter paper. Into a number of 10 mL tubes, 1 mL of procaine HCl was added followed by 1 mL of Sodium nitrate then 1 mL of 0.1 M HCl. This resulting mixture was thoroughly mixed by shaking the tubes vigorously. Then into this mixture, 2 mL of the sample was added followed with 1 mL of NaOH after which the entire was vigorously shaken to mix it properly. The entire mixture was then diluted with distilled water and mixed very well. After about 15 minutes, the absorbance of the azo dye was measured at 507 nm against

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a reagent blank containing the same components apart from the sample using a VU-Visible Spectrophotometer[9].

The same steps were carried out using the standard stock solution in place of the sample. Thiamine concentration in the sample was calculated using;

$$Thiamine\ (mg/100\ g\ dry\ matter) = \frac{C * V}{weight\ of\ sample} * 100$$

Where:

C = concentration of niacin from standard curve (mg/mL)

V = final volume of extract (mL).

3.8.3 Vitamin B2 (Riboflavin)

1. Apparatus/Reagent:

Weighing Balance

0.1N NaOH

Riboflavin

UV-Visible Spectrophotometer

Stock Solution (1000 ppm of riboflavin): 100 mg of riboflavin was dissolved in 100 mL of 0.1 N NaOH give 1000 ppm stock solution.

Standard Stock Solution (100ppm of riboflavin): 10 mL of the stock solution was taken and diluted up to 100ml with 0.1 N NaOH to produce a concentration of 100 ppm solution.

Preparation of Working Standard and Calibration Curve

From the standard stock Solution, 5 ppm, 10 ppm, 15 ppm, 20 ppm, 25 ppm and 30 ppm were prepared by diluting 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 mL respectively to 10 mL of 0.1 N NaOH to get the working standard. The working standard

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solutions are read in the UV-Visible spectrophotometer at 445 nm using 0.1 N NaOH as a blank[9].

2. Procedure

Into a centrifuge tube, 0.5 g of the sample was put into a centrifuge tube to which 15 mL of 0.1 N NaOH was added and was heated in a water bath at about 60 °C for 30 minutes and was cooled to room temperature followed with centrifugation for about 10 minutes. The centrifuged mixture was then filtered using a Whatman filter paper after which the residue remaining on the filter paper was rinsed with 5 mL of 0.1 N NaOH. The supernatant collected was then diluted with 0.1 N NaOH to the 25 mL mark on the volumetric flask. The absorbance of the solution was read at 445 nm with a UV-Visible spectrophotometer using 0.1 N NaOH as blank.

3.9 Mineral Analysis Determination Procedure

3.9.1 Calcium, Sodium and Magnesium Determination

A 2 gm of sample was poured into a crucible and placed in a muffle furnace at 550 ºC for 4 hours until a light gray ash was obtained. Then, to the ash was added 10 mL of 1:1 HCl (HCl: water) which was gently heated. Afterwards, the solution was filtered and the residue was discarded. The supernatant obtained was diluted to mark with distilled water. The solution was feed into the Atomic Absorption Spectophotometry (AAS) with the appropriate wavelengths for each mineral as well as their conditions[10].

$$\%\ Ca, Na\ and\ Mg = \frac{C * V}{weight\ of\ sample} * 100$$

Where;

C = concentration from AAS (mg/mL)

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V = final volume of extract (mL)

3.9.2 Calcium, Sodium and Magnesium Determination

This method is used to determine the percentage amount of Calcium and Sodium in a sample. Although it is not ideal to calculate that of Magnesium, it however can be employed but under strict practices that must be adhered to in order to get accurate results.

1. Apparatus: Heating mantle, Crucible, Glass rod, Flame photometer, 100ml Volumetric flask, Whatman No. 1 Filter paper, Wash bottle, 10ml pipette, funnel.
2. Reagents: 2 MHCl
3. Procedure: The ash of each sample obtained was digested by adding 5mL of 2 M HCl to the ash in the crucible and heating to dryness on a heating mantle. 5mL of 2 M HCl was added again, heated to boil, and filtered through a Whatman No. 1 filter paper into a 100ml volumetric flask. The filtrate was made up to mark with distilled water, stoppered and made ready for reading of the concentration of Calcium, Sodium and Magnesium on the Jenway Digital Flame Photometer (PFP7 Model) using the filter corresponding to each mineral element[10]. The concentration of each of the elements was calculated using the formula:

$$\%\ Ca\ or\ Na\ or\ Mg = \frac{meter\ reading * slope * dilution\ factor}{1000}$$

3.9.3 Phosphorus Determination

Routine determination of phosphorus was done by the Vanado-molybdate colorimetric or spectrophotometric method. The ash of each sample obtained was treated with 2 MHCl solution as described for calcium determination previously. 10 mL of the filtrate solution was pipetted into 50 mL standard flask, 10 mL of Vanadate yellow solution was added and with distilled water to make it up to the mark, stoppered and allowed for 10 minutes

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for full yellow development. The concentration of phosphorus was determined by taking the optical density (OD) or absorbance of the solution on a spectronic 20 spectrophotometer or colorimeter using a wavelength of 470 nm[10]. Phosphorus percentage was calculated using this formular;

$$\%\, phosphorus = \frac{absorbance * slope * dlution\ factor}{1000}$$

3.9.4 Zinc, Iron and Manganese Determination

The ash of the digest of each sample above as obtained in calcium and magnesium determination was mixed with 10 mL of nitric acid and heated gently to dissolve all the ash after which it was transferred to a volumetric flask to which de-ionized or distilled water was added to make up to 100 mL. The diluent was then aspirated into the Buck 200 Atomic Absorption Spectrophotometer (AAS) using the suction tube. The hollow cathode lamps using appropriate fuel and oxidant combination were used to read the trace elements at their individual wavelength.

The samples were analyzed chemically in accordance with the official methods of analysis and were all duplicated.

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Chapter Four

Results and Discussion of Findings

4.1 Results

This chapter presents the results of the analysis carried out on biodegradation of sweetcorn cob using edible fungi (*Pleurotus ostreatus*, *Pleurotus pulmonarius* and *Pleurotus citrinopileatus)*in a circular economy approach. The chapter specifically address each research objective in a systematic order. First, the assessments of rate and extent of biodegradation of the substrate, monitoring of the mycelial growth rate, detailed analysis of the chemical composition of the substrate, vitamin and mineral composition analysis. The results can be found in both tabular and explanatory formats and provide an understanding of the biochemical and agronomic changes brought about by the fungal activity.

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Table 4.1: The Extent and Rate of Degradation of Corn Cobs Degraded with Different Fungi in a 3-day Interval (kg)

Degraded Corn Cobs (DCB)	**Day 3**	**Day 6**	**Day 9**
DCB- *Pleurotus ostreatus*	461.40[c]	458.61[c]	453.00[c]
DCB -*Pleurotus pulmonarius*	472.40[b]	466.60[b]	459.40[a]
DCB -*Pleurotus citrinopileatus*	483.20[a]	477.00[a]	465.40[a]
SEM	5.00	3.50	2.00

Source: author's laboratory work, 2025

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The rate and extent of biodegradation measured in kg at three-day intervals for fourteen days revealed that as the day increased, the rate of fungi degradation decreased (*Pleurotus pulmonarius* from 472.40 – 459.40, *Pleurotus ostreatus* from 461.40 – 453.00 and *Pleurotus citrinopileatus* from 483.20 – 465.40). It was observed that the weight of the degraded sweetcorn cob reduced with increase in degradation days. The relatively low biodegradation rate indicates significant biological mass loss and gives evidence that the fungi (*Pleurotus spp*) successfully colonized the substrate and degraded the lignin,

cellulose and hemicellulose contents of the substrate turning them from complex compounds to simple compounds.

Table 4.2: Linear Mycelia Growth (cm) of Corn Cobs Degraded with Different Fungi in 3-day Intervals

Degraded corn cobs (DCB)	**Day 3**	**Day 6**	**Day 9**
DCB- *Pleurotus ostreatus*	2.30[a]	4.16[a]	5.80[a]
DCB -*Pleurotus pulmonarius*	1.94[b]	4.16[a]	5.86[a]
DCB -*Pleurotus citrinopileatus*	1.30[c]	3.00[b]	4.78[b]
SEM	0.25	0.35	1.55

Source: author's laboratory work, 2025

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Table 4.2 evaluated the mycelial growth rate of the three fungi measured in centimeters at three-day intervals for fourteen days. The growth increased significantly as the days of degradation increased. The fungi were able to colonize the substrate with *Pleurotus pulmonarius* having the first initial growth from 1.94 – 5.86, *Pleurotus ostreatus* from 2.30 – 5.80, and *Pleurotus citrinopileatus* from 1.30 – 4.78. The increase in mycelial growth rate indicated that fungi had a balanced growth rate which enabled them not to exceed their nutrient availability too fast thus leading to improved performance on the substrate.

Table 4.3: Chemical Composition (%) of Ramified Corn Cobs Degraded with Different Fungi

Parameters	DCB- *Pleurotus ostreatus*	DCB -*Pleurotus pulmonarius*	Undegraded corn cob	SEM
Dry matter	95.51	95.50	95.17	1.05
Crude protein	1.89[b]	2.14[a]	0.94[c]	0.02
Crude fiber	31.81[b]	27.00[c]	41.67[a]	1.05
Ether extract	0.60[b]	0.44[c]	0.87[a]	0.03
Ash	26.74[c]	24.34[b]	1.07[c]	0.42
Neutral detergent fiber	65.71[b]	55.77[c]	74.10[a]	2.55
Acid detergent fiber	38.38[b]	32.65[c]	49.01[a]	1.50
Acid detergent lignin	6.89[b]	6.33[c]	8.06[a]	0.40
Hemicellulose	27.34[b]	26.32[c]	40.95[a]	0.50

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Cellulose	31.49[c]	35.20[b]	47.91[a]	1.55

Source: author's laboratory work, 2025

In table 4.3, the chemical composition analysis result differed significantly (≤0.05) among the treatments and only the dry matter was similar. Comparing the chemical composition of the degraded and undegraded sweetcorn cob, it was observed that there was a reduction in cellulose, hemicellulose, crude fiber, acid detergent fiber, neutral detergent fiber and ether extract due to enzymatic actions on the corn cob converting them to simpler compounds for fungal growth. Crude ash, crude protein increased as a result of the reduction in the lignocellulosic content of the sweetcorn cob by the fungi, which enables digestibility by ruminants which support its use as animal feed.

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Table 4.4: Mineral Composition of Ramified Corn Cobs Degraded with Different Fungi

Degraded corn cobs (DCB)	Macro mineral (%)				Micro mineral (ppm)		
	Ca	**P**	**K**	**Mg**	**Fe**	**Mn**	**Zn**
DCB- *Pleurotus ostreatus*	1.666[b]	0.288[b]	0.266	0.723[a]	0.678[b]	105.80[a]	11.471[a]
DCB -*Pleurotus pulmonarius*	1.749[a]	0.312[a]	0.394	0.671[b]	0.702[a]	103.38[b]	11.214[b]
Undegraded corn cobs (control)	0.178[c]	0.063[c]	0.479	0.047[c]	0.317[c]	5.52[c]	7.829[c]
SEM	0.02	0.05	1.00	0.03	0.05	5.55	2.35

Source: author's laboratory work, 2025

From Table 4.4, mineral evaluation revealed significant macro and micro nutrient enrichment after fungal degradation. Macro minerals: Calcium, Phosphorus, Magnesium, all increased while Potassium reduced. Microminerals: Iron, Manganese, Zinc, all

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increased after fruiting. The process of transformation of agricultural wastes by fungi increased the nutrient in the substrate.

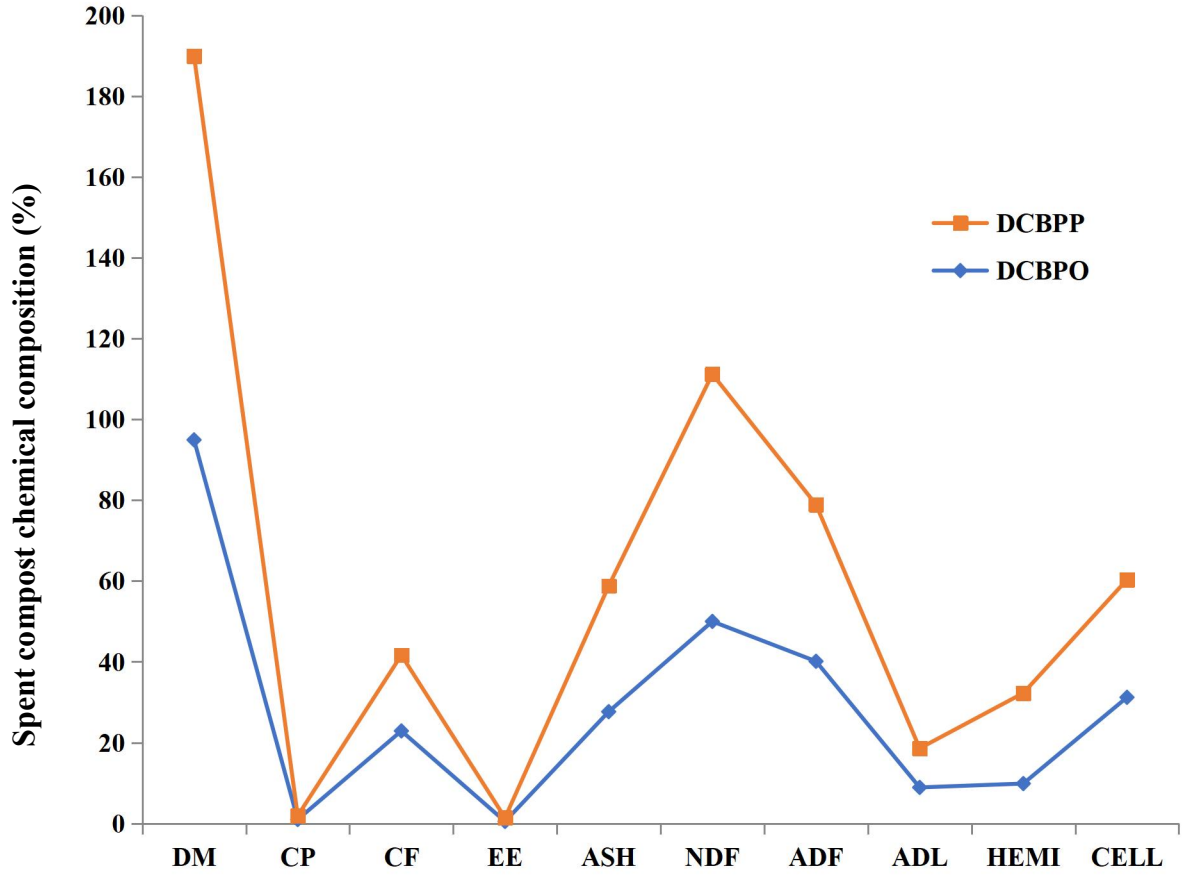
Table 4.5: Vitamin Composition (%) of Ramified Corn Cobs Degraded with Different Fungi

Degraded corn cobs (DCB)	**Thiamine (B1)**	**Niacin (B3)**	**Riboflavin (B2)**
DCB- *Pleurotus ostreatus*	0.459[a]	0.061[a]	0.059[a]
DCB -*Pleurotus pulmonarius*	0.478[a]	0.061[a]	0.056[a]
Undegraded corn cobs (control)	0.302[b]	0.038[b]	0.027[b]
SEM	0.05	0.02	0.001

Source: author's laboratory work, 2025

From Table 4.5, fungal colonization markedly increased the level of vitamin content of the substrate. Thiamine, niacin, and riboflavin, which are essential vitamins found in sweetcorn cob all increased after biodegradation as a result of the enzymatic action of the fungi on the substrate giving it the potential to be used as biofertilizer or livestock feed.

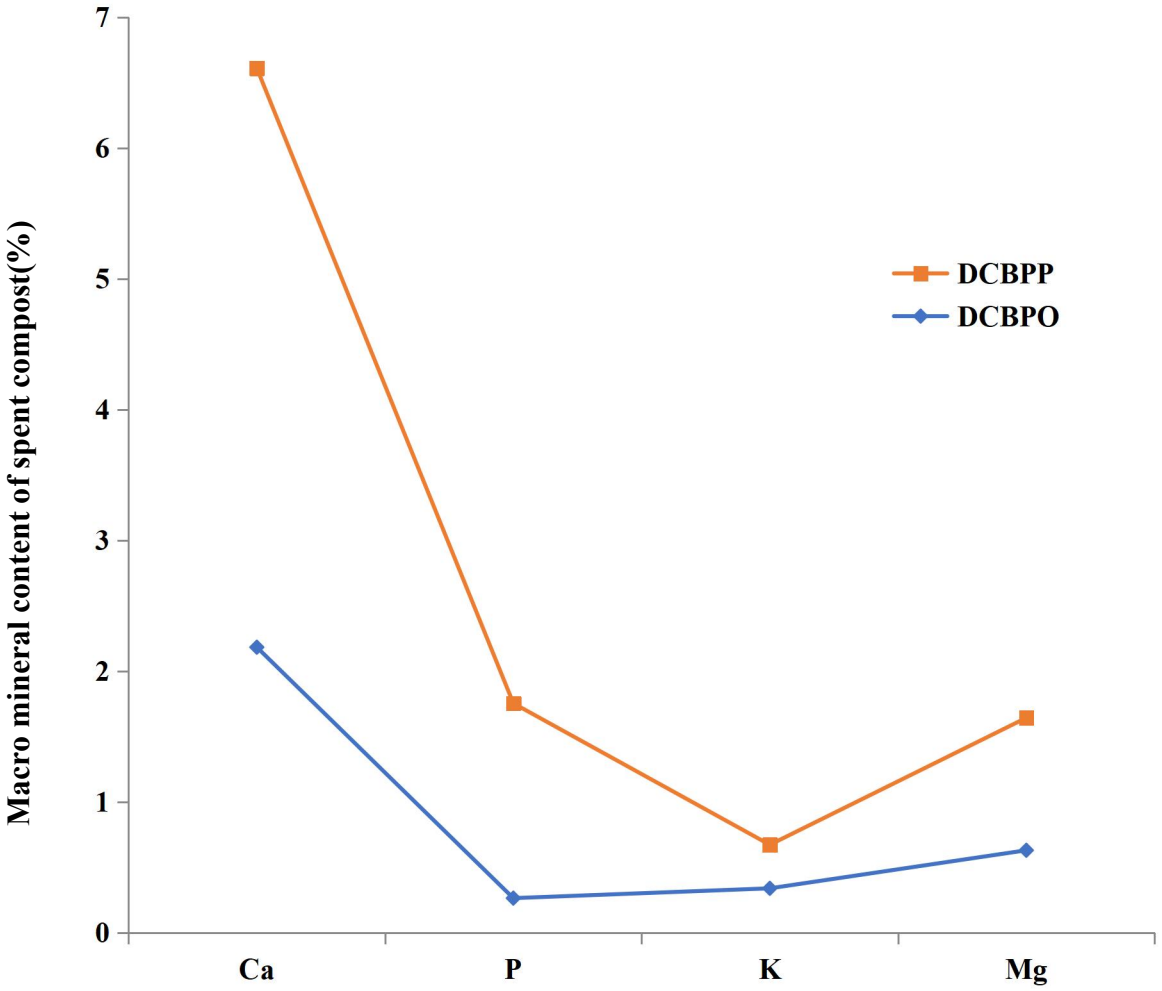
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Source: author's data analysis, 2025

Figure 4.1: Chemical Composition of Spent Compost of Corn Cobs Degraded with Different Fungi

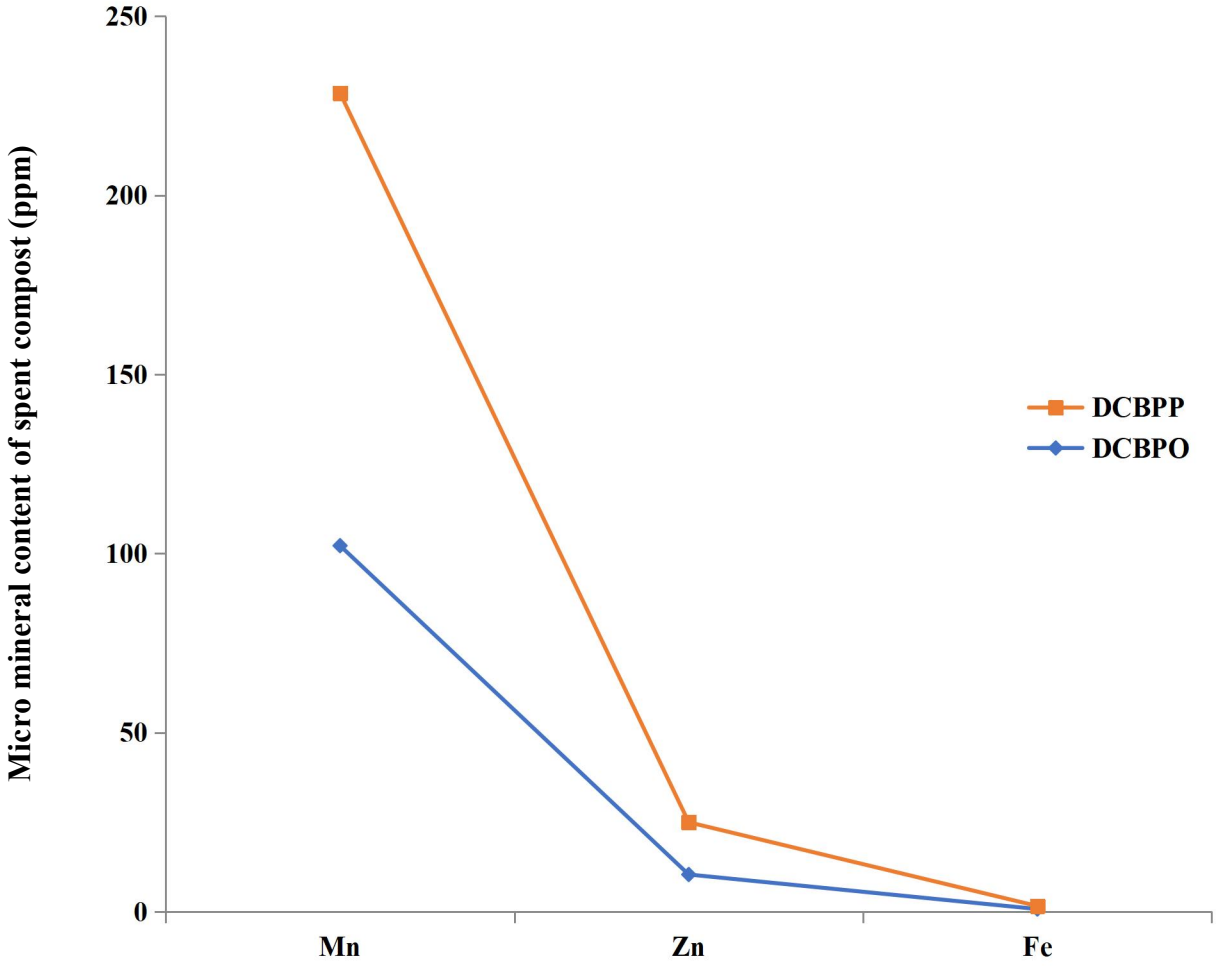
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Source: author's data analysis, 2025

Figure 4.2: Macro Mineral Composition of Spent Compost of Corn Cobs Degraded with Different Fungi

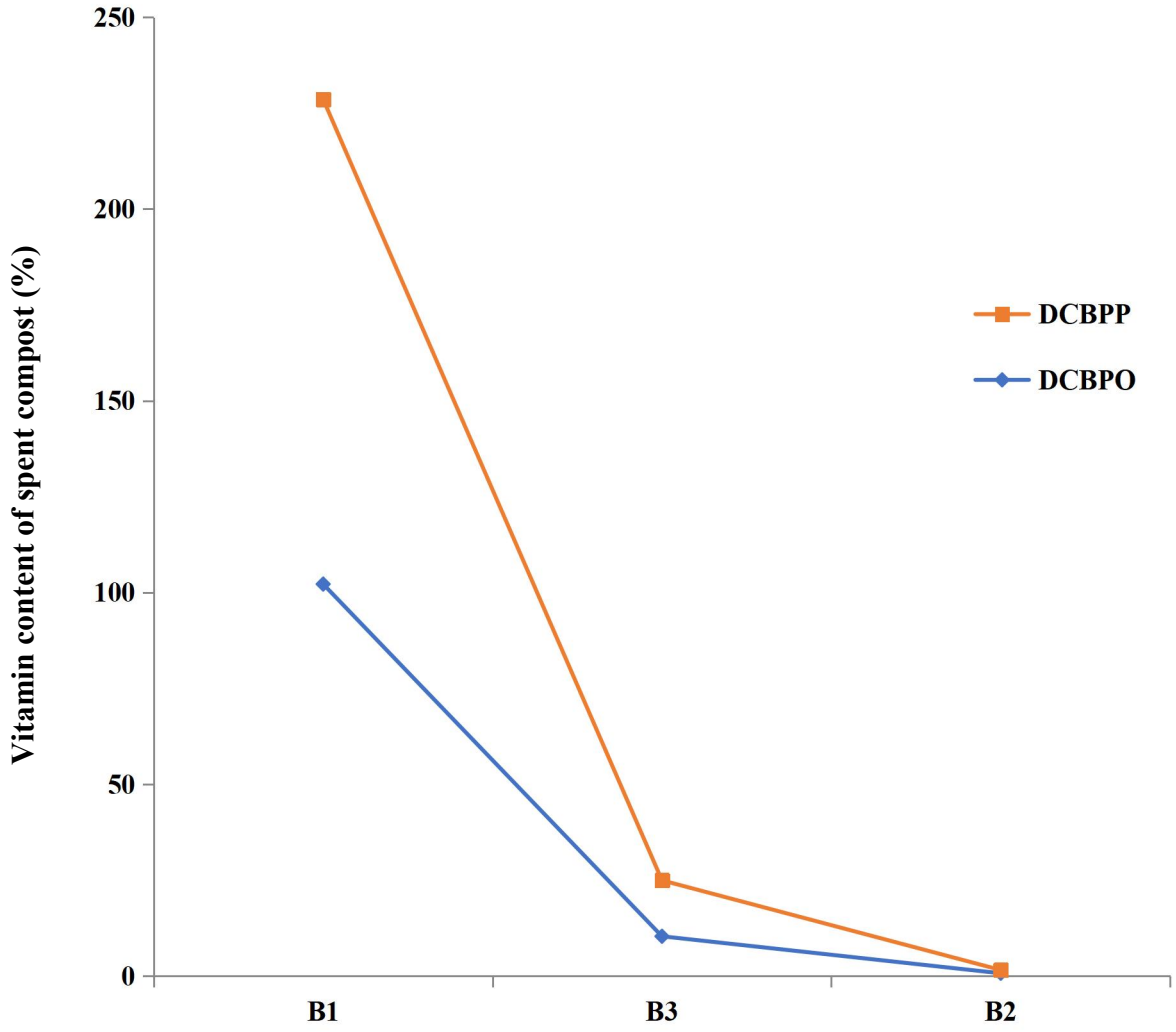
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Source: author's data analysis, 2025

Figure 4.3: Micro Mineral Content of Spent Compost of Corn Cobs Degraded with Different Fungi

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Source: author's data analysis, 2025

Figure 4.4: Vitamin Content of Spent Compost of Corn Cobs Degraded with Different Fungi

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4.2 Discussion of Findings

Agricultural wastes not disposed properly contribute to environmental pollution by raising the level of greenhouse gas emission[1]. Agricultural waste is made up of polysaccharide degraded by the lignocellulolytic enzyme in *Pleurotus pulmonarius, Pleurotus ostreatus* and *Pleurotus citrinopileatus*[2]. The reduction in the lignocellulosic content of these wastes reveals the capacity of fungi to effectively degrade the fibrous content of the cob. The lignocellulosic content of agricultural wastes reduced using *Pleurotus ostreatus* for biodegradation which led to the production of mushroom and using *Pleurotus pulmonarius* led to the increase in digestibility of the spent substrate for ruminants as feed.[3] The results showed notable differences in the degradation efficiency, enzymatic activities and compositional changes among the three fungal species.

The measurement of rate and extent of biodegradation of sweetcorn cob shows that *Pleurotous species* are good bio-degraders having lignocellulotic enzymes that could effectively breakdown the lignocellulosic content of the agricultural wastes.[4] There was reduction in the lignin, cellulose and hemicellulose content of the degraded sweetcorn cob compared to the untreated control.

The three fungi successfully colonized the sweetcorn cob substrate which confirmed the fungal growth ability of sweetcorn cob.[5] Previous works have illustrated that specific colonization rate on agricultural wastes substrate can vary among species which is an important factor in competing for colonization and time to fruit.[6] The variation in mycelial growth rate shows that there is difference in substrate utilization efficiency.

The process of biodegradation enhances notable reduction in total organic matter. Reduction in carbon content and increase in Nitrogen indicates the mineralization of

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organic carbon and fungal biomass accumulation. It enhanced nutritional quality of the biodegraded substrate enabling its use as animal feed or soil amendment.[7]

The enrichment of protein content in the spent substrate aligns with the report that fungal biomass contributes nitrogen-rich compounds during solid-state fermentation, improving the nutritional value of low-protein agricultural wastes.[8]

An increase in vitamin content by the fungi shows their ability to bio-transform lignocellulosic materials in the cob into a nutritious substrate. They are good at breaking down the lignocellulosic contents of the substrate contributing to the biosynthesis and release of bioavailable nutrients which include essential vitamins. Also, the fungal mycelium rich in vitamins becomes part of the substrate during the biodegradation process.[9]

Comparing the chemical composition, mineral contents and vitamin contents of spent compost (substrate after growing mushrooms on it) using the line graph, it has been revealed that *Pleurotus pulmonarius* has higher efficiency and capability to degrade the sweetcorn cob out of the two fungi used (*Pleurotus pulmonarius* and *Pleurotus ostreatus*). *Pleurotus citrinopileatus* could not grow as a result of high temperature and harsh weather. Various researches show that *Pleurotus pulmonarius* produced high level of extracellular proteases when grown on agricultural waste. These enzymes facilitate the release of amino acids and bound vitamins during the biodegradation process.[9] Also experiment using spent compost on which *Pleurotus pulmonarius* was grown shows the enrichment of bio-active compounds which transform the waste to nutritionally valuable compounds. The chemical composition of spent compost degraded by *Pleurotus pulmonarius* had high calcium and potassium content due to the organic matter degradation and the deposited protein content in and by the fungi while phosphorus,

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magnesium and manganate content decreased due to fungal uptake of the minerals in the sweetcorn cob.[9] Decrease in vitamin content of the spent compost is due to fungal metabolism, degradation and uptake into the fruiting bodies. *Pleurotus pulmonarius* increased the antioxidant potential of the mushroom and adds vital micronutrients to the substrate[10]. Research on sweetcorn waste is generally not common in Nigeria because sweetcorn is gradually being accepted in Nigeria; however, comparing the result of my research with other researchers where different substrates were used, shows that fungi have strong degradative capacity. Results of the research work carried out by some researchers on this subject are listed below.

Research work carried out on groundnut shells using *Aspergillus niger* and *Trichoderma viride* to degrade it. From the research, there was increase in crude protein and fat content alongside the decrease in crude fiber, tannins and oxalates.[11] This improved the nutritional content of the groundnut shell and their sustainability to be used as animal feed.[12]

Also, it was revealed in another research using the conventional maize that after degradation of the cob using edible fungi, protein and fiber content increased supporting the idea of using the substrate to produce animal feed; turning waste to wealth in a circular economy, which is applicable in my findings.[13]

Furthermore, edible fungi having lignocellulolytic enzymes could effectively degrade the complex compound in agricultural residue which is useful in waste management and sustainable agricultural practices to achieve a “zero waste” economy.[13]

The research on the biodegradation of three agricultural wastes(rice bran, maize leaves and sugarcane bagasse) using *Pleurotus pulmonarius* pointed out increase in protein and

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nutrient composition and the fact that fungi grown on agricultural waste convert waste to nutritious food, reducing waste which aligns with my research work.[14]

Development in biotechnology reveals that agricultural wastes can be degraded effectively by fungi. These wastes are made up of compounds from phenol and other compounds that can have adverse effect on the ecosystem when not well treated.[1] The lignocellulosic materials in wastes can be transformed to raw materials in industries for manufacturing various products when biologically treated by the lignocellulolytic enzymes in fungi.[8]

The circular economy approach demonstrates that sweetcorn cob, an under-utilized agricultural waste can be transformed biologically through fungal bioprocessing which promotes sustainable waste management, resource recovery and environmental protection.[11]

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Chapter Five

Conclusion

5.1 Summary of Findings

The study showed that edible fungi (*Pleurotus Species*) could effectively degrade sweetcorn cob (agricultural wastes). The lignocellulosic contents of the cob were broken down by the lignocellulotic enzymes in the fungi.[1] The *Pleurotus pulmonarius* showed the fastest growth rate and highest degradation rate followed by *Pleurotus ostreatus* and *Pleurotus citrinopileatus,* which grew slowly.

Chemical analysis of the degraded corn cob showed reduction in lignin, cellulose and hemicellulose content of the cob, the fungi transformed the waste into a more useful product (animal feed and mushroom).[2]

The biotransformation reduced waste as well as enhancing the nutritional components of the substrate enabling its potential use as soil amendments or animal feed supplement.[3]

In summary, *Pleurotus* species have degrading abilities suitable for biodegrading agricultural waste into valuable products promoting sustainable waste management, agricultural practices and food security which produces nutrient-rich mushroom and animal feed as by-product, providing an eco-friendly solution for waste management in a circular economy approach.[4]

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5.2 Conclusion

Biodegradation of sweet corn cob and its subsequent use in mushroom cultivation represents a sustainable approach to agricultural waste management. The cob, which is an unwanted agricultural waste could be useful as raw material for producing useful products like animal feed and substrate for cultivating mushrooms which serves as a valuable resource for improving food security, conversion of waste into wealth instead of discarding them or becoming an environmental nuisance causing pollution[1,5]

Sweetcorn cobs are rich in lignocellulosic materials that serve as a suitable substrate for growing mushroom. The practice closes the gap between waste generation and food production using a circular economy approach. It encourages sustainable agricultural practices, reduces reliance on synthetic substrates and minimizes environmental pollution and also supports the production of protein-rich, medicinal and commercially valuable mushroom.[3]

The sweetcorn cobs being readily available after harvest, offer a viable and cost-effective alternative to conventional substrates such as straw. Natural breakdown of sweet corn cob by microbial communities enriches substrates by making nutrients more bioavailable thus enhancing the growth performance and yield of mushrooms such as *Pleurotus species* which can reduce the need for synthetic fertilizers and contribute to soil health when the spent substrate is returned to the land as compost or organic fertilizer.[6]

Mushroom cultivation on agricultural wastes is beneficial for plants, animals and human beings. It has become a profitable business because of the rise in demand in the market for edible mushroom which is an alternative protein source for human beings.[7]

Discoveries of this study shows that transition to a circular economy in agriculture offers the opportunity to turn waste into wealth by adopting new innovative technologies and

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sustainable practices which turns agricultural wastes to valuable products.[6] It transforms low-value wastes into nutritious food supporting sustainable agriculture, reducing environmental impact and creating socio-economic benefits.[3]

This approach promotes:

1. Turning wastes into valuable products
2. Nutrient recycling
3. Rural development by supporting local economies
4. Sustainable food production
5. Reduction in landfill
6. Reduction in pollution (greenhouse gas emission)

However, the transition requires coordinated efforts across technology, policy, finance and education. The use of edible fungi to biodegrade agricultural wastes supports rural entrepreneurship and local food systems contributing to a regenerative agricultural economy.

5.3 Recommendation

1. Awareness and training programs, workshops should be organized which will incorporate circular economy principles, highlighting the reuse and recycling of agricultural wastes to produce valuable products.

2. Regular health education and enlightenment on waste management and disposal.

3. Conducting a feasibility assessment on the sustainability and profitability of the system.

4. Encourage farmers to go into mushroom farming using agricultural wastes by offering them loans, grants.

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5. Collaboration between research institutions, NGOs, private sector to scale up waste-wealth solutions.

6. Carry out more scientific research on the biodegradation process to detect the best fungal strain suitable for each substrate to produce improved yield.

5.4 Contribution to Knowledge

This research contributes to the scientific body of knowledge in the following significant ways:

1. Valorization of Agricultural Waste

The study highlights an innovative application of sweet corncob, an underutilized agricultural by-product as a substrate for fungal cultivation. This promotes its conversion from waste into a valuable resource, reducing environmental burden and supporting sustainable waste management[6].

2. Use of Edible Fungi for Biodegradation

The research demonstrates that edible fungi (e.g., *Pleurotus ostreatus, Ganoderma lucidum*) can effectively biodegrade lignocellulosic materials found in sweetcorn cobs. It contributes new insights into the enzymatic mechanisms (e.g., ligninase, cellulase production) these fungi use to break down complex plant polymers.[7]

3. Nutritional and Economic Potential of the Output

Using edible fungi, the biodegradation process results in not just waste reduction but also the production of nutritious mushrooms. This dual-purpose approach aligns with food security goals and provides economic opportunities for small-scale farmers and entrepreneurs[5].

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4. Model for Circular Bioeconomy

The study frames the fungal biodegradation of sweetcorn cobs within a circular economy model where waste is re-integrated into the production cycle. It sets a precedent for zero-waste agricultural systems, offering a replicable and scalable model for other crop residues[5].

5. Environmental Sustainability

The research provides evidence that fungal treatment of corn cobs is a non-toxic, eco-friendly alternative to the traditional waste disposal methods (burning or landfilling) thereby contributing to reduced greenhouse gas emissions and soil pollution[2]

6. Scientific Basis for Industrial Application

By evaluating fungal growth rate, degradation efficiency and nutritional composition of the resulting biomass, this work lays the groundwork for industrial-scale applications in biomaterials, animal feed or bioenergy production.

5.5 Suggested Area of Further Research

Further studies on the use of fungi to degrade agricultural wastes; a circular economy approach could explore broader and important areas. Research could focus on comparing the degradability efficiency of *Pleurotus species* on wastes with the use of other fungi to improve waste utilization. Also investigating the pre-treatment methods (physical, chemical, biological) and the optimal conditions (pH, temperature, moisture, oxygen) needed for effective biodegradation. Additionally, extending the study to the evaluation of the nutritional profile and the safety of the substrate used in the production of animal feed and growing mushrooms, organic fertilizers and biochar. Another potential area is comparing the traditional waste disposal methods (burning, landfilling) with fungal

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biodegradation with respect to waste reduction, reuse, recycling and effects on the ecosystem.

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Lead City University Ibadan DO NOT COPY

Shosanya A. A., Nutritional Content and Biodegradation of Sweetcorn Leaves using Edible Fungi (*Pleurotus pulmonarus*), Lead City University, Ibadan, Oyo State, 2022.

Amadioha A. C., Biodegradation of Agro-waste Polysaccharides by *Pleurotus pulmonarus,* Department of Plant Health Management, Michael Okpara University of Agriculture, Umudike, Umuahia, Abia State, 2023.

Diego Cunha Zied; A Comprehensive Analysis of Biodegradation and Bioconversion of *Lentinula edodes* and other Exotic Mushrooms, Department of Plant Production, College of Agricultural and Technological Sciences, Sao Paulo State University, Brazil, 2023.

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Appendices

Appendix 1

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Figure I: Hip of Sweetcorn Cob

Source: Author's laboratory work, 2025

Appendix 2

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Figure II: Mixing of Shredded Corn Cob

Source: Author's laboratory work, 2025

Appendix 3

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Figure III: Corn Cob in Boling Tubes

Source: Author's laboratory work, 2025

Appendix 4



Figure IV: Bagging of Sweetcorn Cob

Source: Author's laboratory work, 2025

Appendix 5



Figure V: Spun in Bottles

Source: Author's laboratory work, 2025

Appendix 6



Figure VI: Innoculating of Spun to the Substrate in the Innoculating Chamber

Source: Author's laboratory work, 2025

Appendix 7



Figure VII: Tubes and Bags in the Dak Room

Source: Author's laboratory work, 2025

Appendix 8



Figure VIII: Measuring Mycelial Growth in the Tube

Source: Author's laboratory work, 2025

Appendix 9

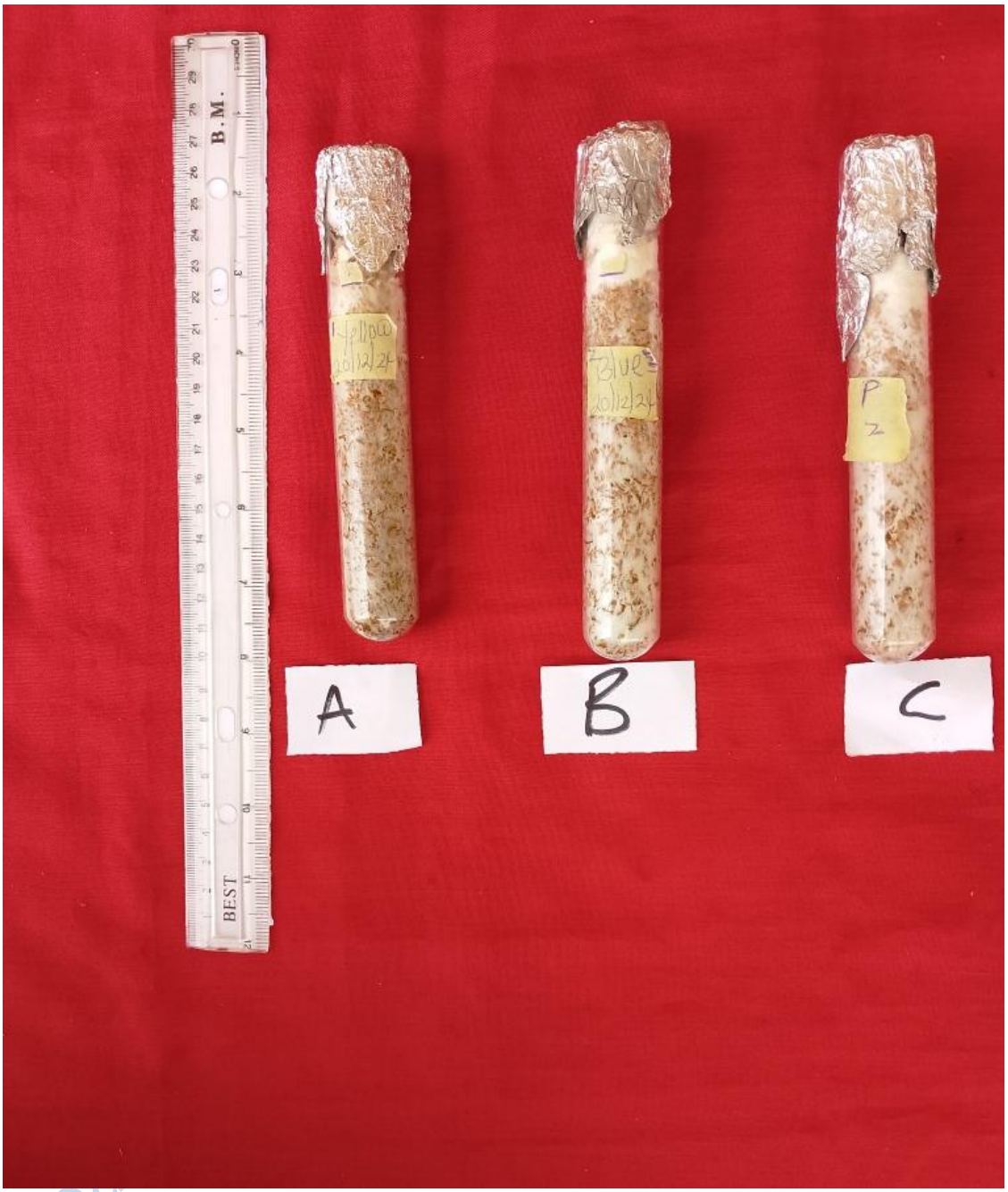


Figure IX: Mycelial Ramification in Tubes

Source: Author's laboratory work, 2025

Appendix 10

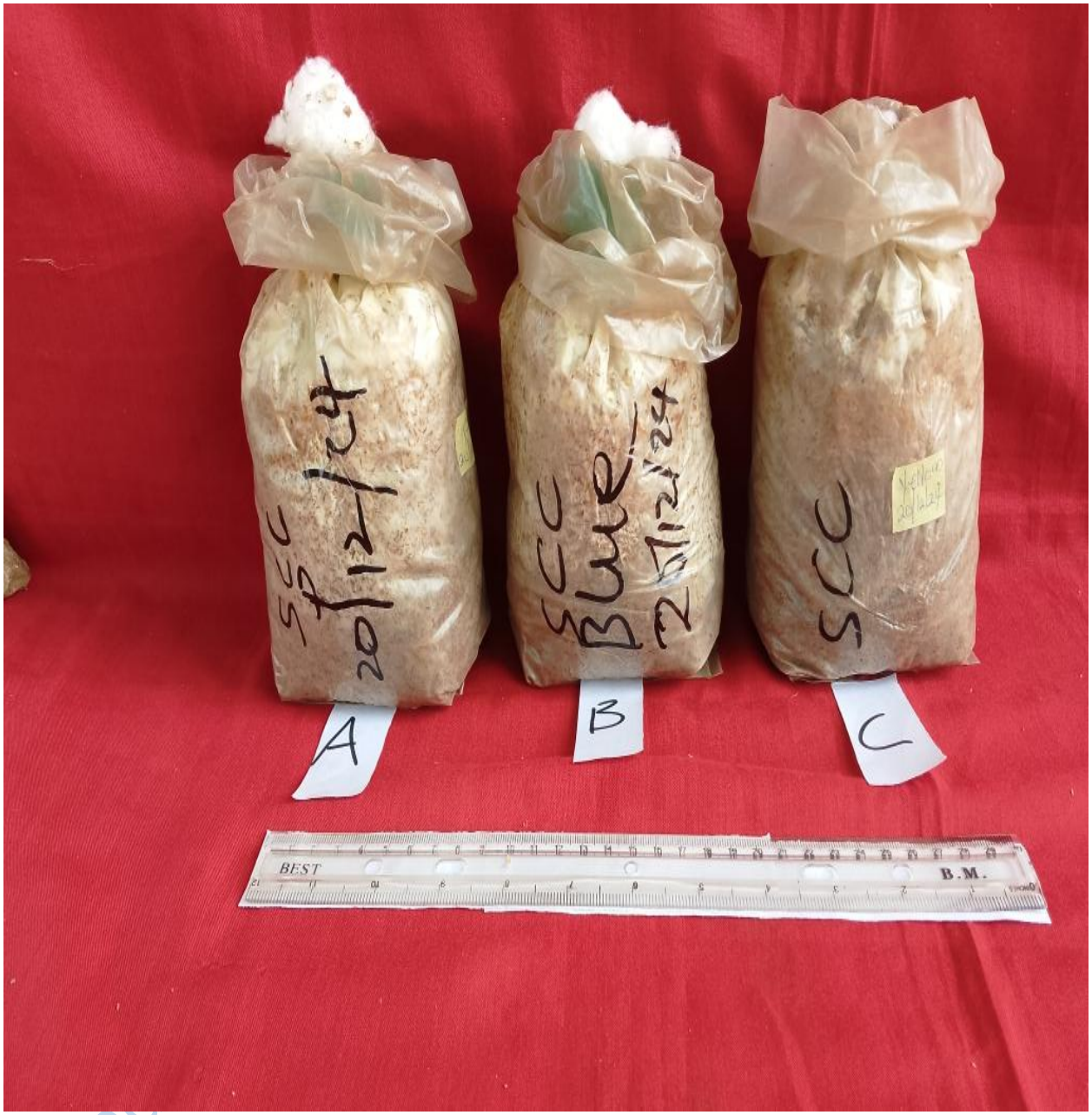


Figure X: Mycelial Ramification in Bags

Source: Author's laboratory work, 2025

Appendix 11



Figure XI: Premodal Initiation of *Pleurotus pulmonarius*

Source: Author's laboratory work, 2025

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Appendix 12



Figure XII: Premodial Initiation of *Pleurotus ostreatus*

Source: Author's laboratory work, 2025

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Appendix 13



Figure XIII: Fully Grown *Pleurotus pulmonarius*

Source: Author's laboratory work, 2025

Appendix 14

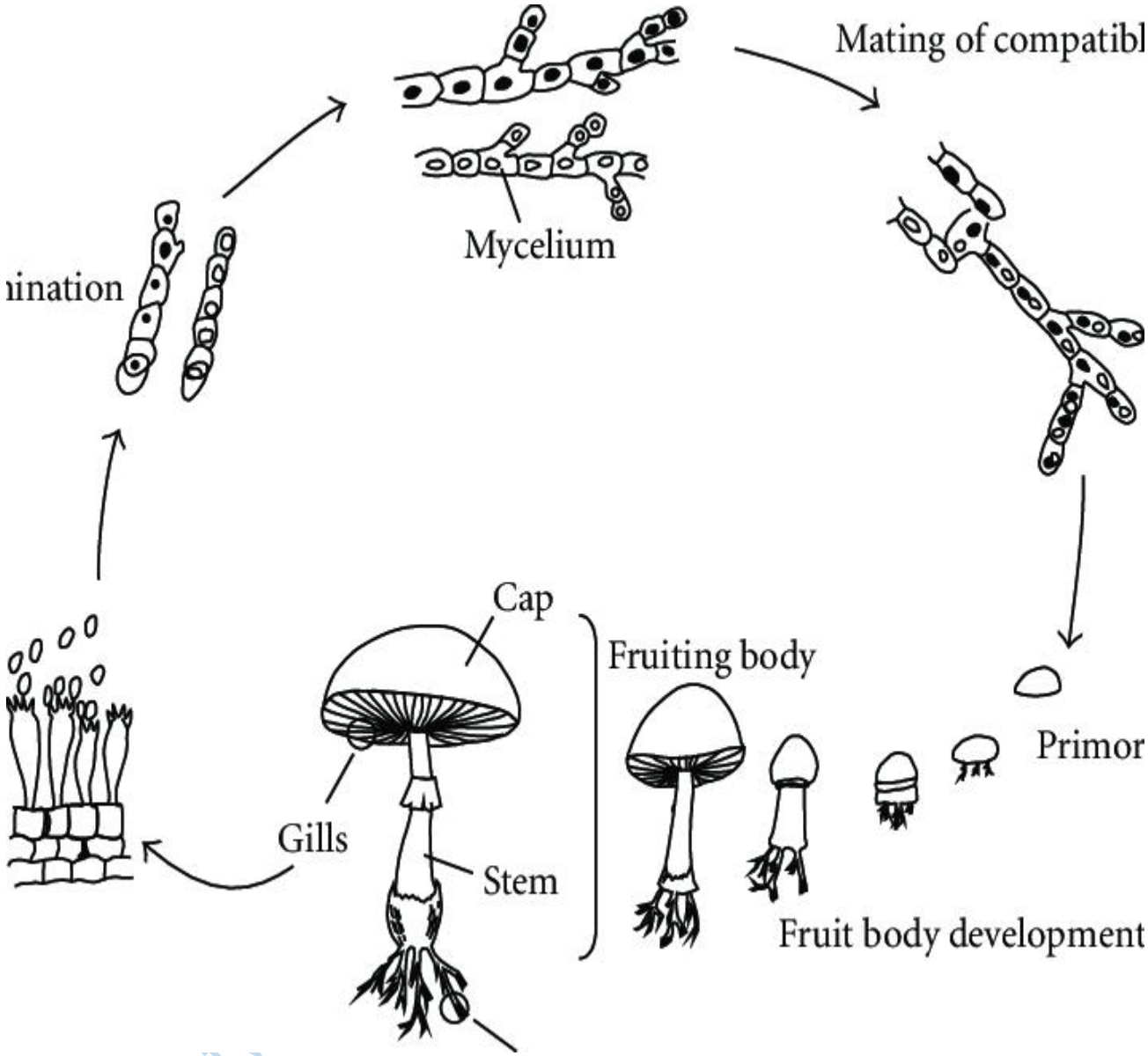


Figure XIV: Fully Grown *Pleurotus ostreatus*

Source: Author's laboratory work, 2025

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Appendix 15



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Figure XV: Life Cycle of Mushroom

Source: ResearchGate

Appendix 16



Figure XVI: Examples of Edible Mushroom

Source: Britannica.com

Appendix 17

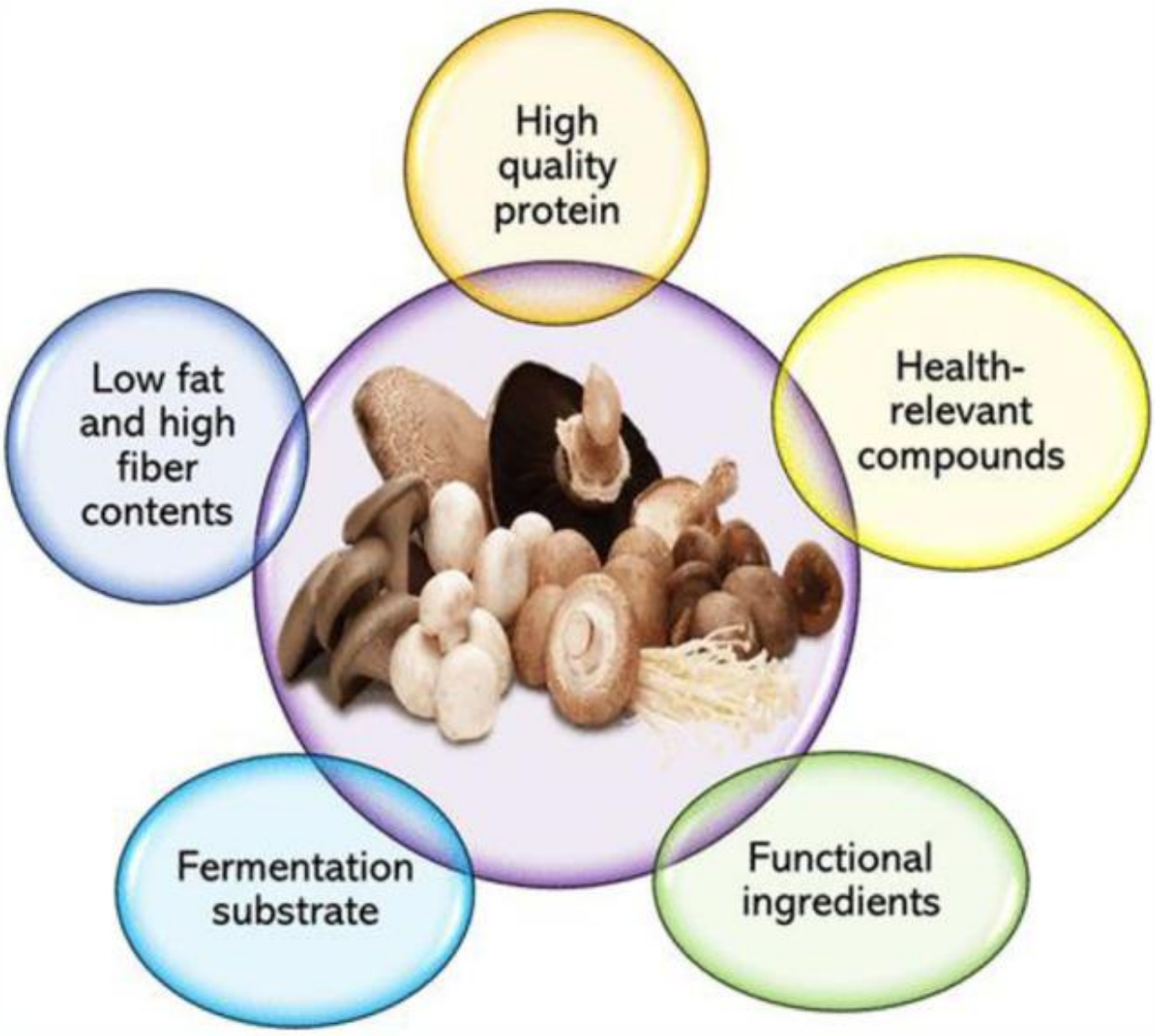


Figure XVII: Mushroom as a Source of Proteins and Functional Ingredients

Source: ResearchGate

Appendix 18

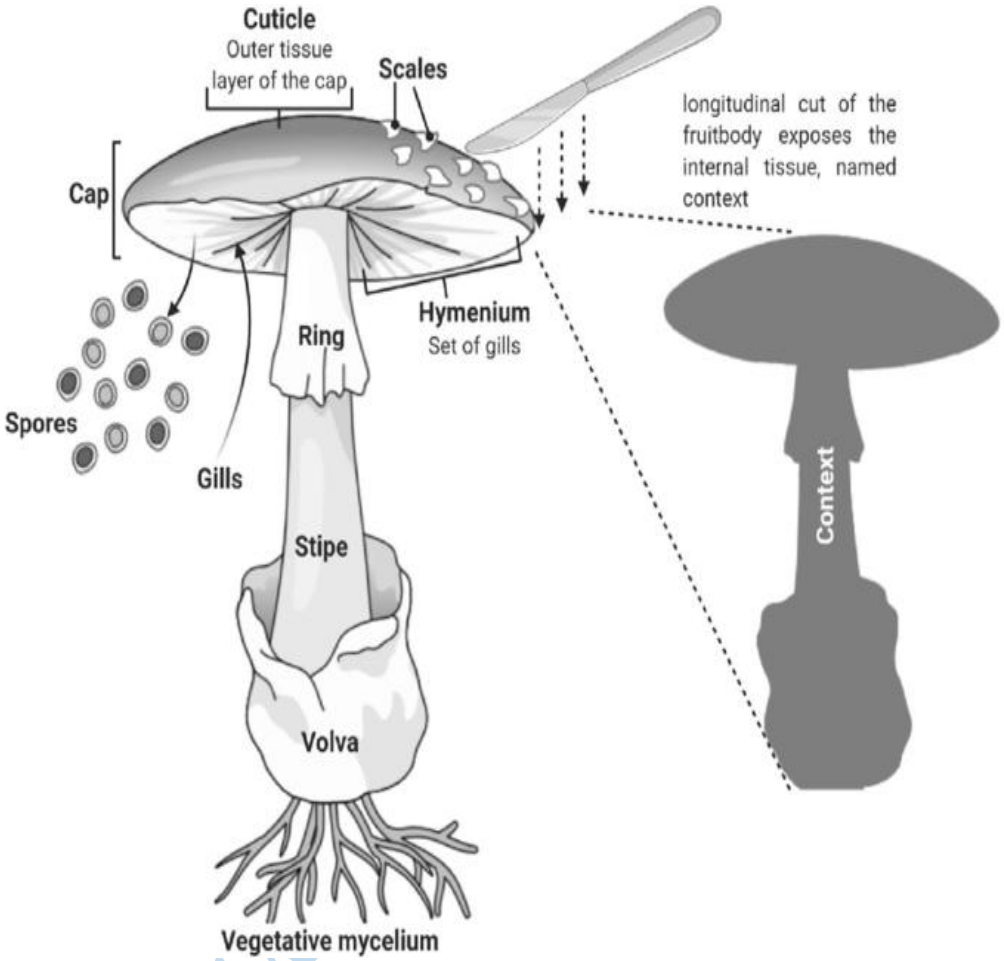


Figure XVIII: Diagrammatic Representation Showing the Structure and Components of an Agarical Fruitbody

Source: ResearchGate

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Appendix 19



Figure XIX: Myself Working in the Analytical Lab

Source: Author's laboratory work, 2025

Bio – data

A: Personal Data

1.	Full name:	SHOSANYA ADENIKE ABIOLA
	Address:	No 8, Waidi Alli. Street, Gbonagun, Obantoko, Abeokuta.
	Email:	abiolanick@yahoo.com
	Phone Number:	08032171552, 09054671452
2.	Date and place of birth	2nd February, 1974, Odogbolu
3.	Nationality	Nigerian
4.	Marital Status:	Married
5.	No of children & ages	Three; 23, 21 & 19
6.	Name & address of spouse	Kayode D. Shosanya, same as above, kentokay_2005@yahoo.co.uk 08053413214, 07067770015.
7.	Name and address of next of kin	Oloruntoniloba R. Kayode, address as above.
8.	Date of assumption of duty in current establishment	1st February, 2012
9.	Status on first appointment in current establishment	Technologist II
10.	Present position	Assistant Chief Technologist
11.	Date of last promotion	October, 2024
12.	Date of confirmation of appointment	1st February, 2014

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13.	Faculty	School of Secondary Education, Science.
14.	Department:	Biology

B. Educational Background

1. Educational Institutions Attended with Dates and Qualifications

Lead-city University, Ibadan	MSc Food Microbiology	2023 -2025
Lead-city University, Ibadan	PGD Microbiology	2020 – 2022
Ekiti State University, Ado-Ekiti	MBA	1999-2001
Osun State Polytechnic, Iree	HND Microbiology	1997-1998
Osun State Polytechnic, Iree	OND Science Lab Tech	1994-1995
Ijebu Igbo Girls Grammar School	SSCE	1984-1990
St. Paul's Anglican School, Omu-Ijebu	Primary School Leaving Cert.	1979-1984

C. Awards & Fellowship

1. Certificate of Merit as General Secretary of Microbiology Students Association, Osun State Polytechnic, Iree '97 Set.
2. Letter of Commendation from FCE Abeokuta for commitment in accreditation exercise
3. Certificate of Commendation from Mountain of Fire and Miracles Ministries as a fellowship leader.
4. Letter of Commendation for active role and commitment in sustaining school of Science Ventures, FCE, Abeokuta.

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D. 1. Work Experience with Dates

i. Finest Aluminum Coy, Ring Road, Ibadan 1997-1998

ii. Guiness Nig. PLC, Oba-Akran road, Ikeja, Lagos 1999-2002

iii. Aboseldehyde Laboratories PLC, Amuwo-Odofin, Lagos 2003-2006

iv. Ondo State Polytechnic, Owo 2006-2011

2. Courses Taught within the Current Academic Sessions

i. NCE 1 Practical

ii. NCE 2 Practical

iii. NCE 3 Practical

E. Membership of Academic Professional Bodies

Associate Member of Nigerian Institute of Science Laboratory Technologists (ANISLT)

F. Publications

1. Thesis & Dissertations

i. Construction of an Electric Stove, OND Project submitted to the Department of Sci. ab. Tech, Osun-State Polytechnic, Iree 1995

ii. Fungal Disease of Cocoa (Case study of black pod disease), HND Project submitted to the Department of Microbiology, Osun State Polytechnic, Iree 1998

iii. Motivation of Workers for Better performance (A case study of FMC, Idi-Aba, Abeokuta, Ogun State), MBA thesis submitted to the Department of Business Admin, Faculty of Social & Management Sciences, University of Ado-Ekiti. 2021

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iv. Nutritional Content and Bio-degradation of Sweet Corn leaves using edible Fungi (*Pleurotus pulmonarius*), PGD thesis submitted to Biological Science Department, Faculty of Natural & Applied Sciences, Lead-City University, Ibadan.

2022

v. Biodegradation of Sweetcorn Cob Using Edible Fungi: A Circular Economy Approach, MSc thesis submitted to Biological Science Department, Faculty of Natural and Applied Sciences, Lead city University, Ibadan. 2025

2. Paper Accepted for Publication

Bioconversion of Sweetcorn Cob Using Edible Fungi: Evaluating Degradation Efficiency and Nutritional Transformation 2025

3. Book Reviews and Commentaries in Scholarly Journals

Shosanya, A.A *et al.,* (2022); Comparative Analysis of Laboratory Safety Practices Among Public and Private Schools (Biology students & teachers) In Odeda local government, Ogun State. Published in Journal of Science Education, FCE Abeokuta. Vol. 16, No 1. June 2022.

Shosanya, A.A *et al.,* (2023) Effects of Blended Teaching Instructional Approach on the Performance of Biology Students in Public & Private Senior Secondary Schools in Abeokuta South, Ogun State; Journal of the Department of Science Education, Federal College of Education, Abeokuta. Published in the African Journal of Science, Technology and Mathematics Education 2023.

Shosanya, A.A *et al.,* (2025) Bioconversion of Sweetcorn Cob Using Edible Fungi; Evaluating Degradation Efficiency and Nutritional Transformation. Published in

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International Journal of Progressive Research in Engineering Management and Science (IJPREMS)-Volume 5 Issue 7, July 2025.

4. Major Conferences/ Workshops Attended

i. Seminar on "Administrative Procedures & Duties" by FCE Abeokuta registry department 2012.

ii. Seminar on "Health lifestyle as a panacea for enhancing great health" by FCE Abeokuta Cooperative Society 2019.

iii. Seminar on "Preparation for retirement" by FCE Multipurpose Society Limited 2019

iv. Seminar on "Engaging the essential work of Care" for Cooperative members FCE, Abeokuta. 2021.

v. International Seminar on "UN & UNESCO World day for Cultural diversity for dialogue and development" 2024.

vi. Research training for all Postgraduate Students; AI Research and Grant Writing Training (Nov, 2024)

vii. Training on Artificial Intelligence Tool for Teaching & Research Workshop (October 2024).

5. Services Outside the University

Social & Religious

i. House fellowship leader, Mountain of Fire & Miracles Ministries SW 1 Region, Asero, Abeokuta since 2008

ii. Member, Old Girls association, IGGS, Ijebu-Igbo

iii. Member, Iree Connect '97.

iv. Member, women foundation, Mountain of Fire & Miracles Ministries

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v. Member, Ore-Ofe Community, Gbonagun, Obantoko, Abeokuta.

vi. Member, Ondo State indigenes, FCE Abeokuta.

Administrative Position Held

i.	General Sec., Association of Microbiology Students Osun- State Polytechnic, Iree	1997-1998
ii.	Secretary, School of Science Ventures, FCE Abeokuta	2014-2016
iii.	Member, School of Science Environmental Committee	2016-2018
iv.	Secretary, School of Science Ventures	2018-2020
v.	Secretary, School of Science Ventures	2020-2022
vi.	Secretary, School of Science Ventures	2020-2024
vii.	Treasurer, Association of Technologists, FCE, Abeokuta	2021-till date
viii.	Secretary, Biology department welfare committee	2022 till date
ix.	Treasurer, Association of IGGS 1990 set	2018 till date
x.	Treasurer, Venerable Ojomo's descendant	2016 till date
xi.	Member School of Science FCE Abeokuta Welfare Committee	2024-2026
xii.	Member FCE Abeokuta Staff Welfare Committee	2024-2026

G. Extra-curricular Activities

1. Listening to music
2. Travelling

J. Name and Address of Referees

1. **Prof. A. Abiala**

   Department of Mathematics

   University of Lagos

   Lagos.

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08056060214

2. **Professor Bukola Bamkefa**

   Department of Biological Sciences

   Lead City University, Ibadan.

   08035268612

3. **Dr. Joy Abiola Onipede**

   Department of Biology

   F.C.E Abeokuta.

   08060155009

_____ _____

Date **Signature**

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University Compliance Certification

This is to certify the thesis by Shosanya, Adenike Abiola with matric number LCU /PG/002607 in the department of Biological Sciences, Faculty of Natural and Applied Sciences, Lead City University, Ibadan is in full compliance with the approved format and style.

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_____ _____

Name **Date**