Importance of Fungi in the Petroleum, Agro-Allied, Agriculture and Pharmaceutical Industries

Leera Solomon, Vulebari Pius Tomii and Asiton-a Asifamabia Dick

Department of Science Laboratory Technology, School of Science and Technology, Captain Elechi Amadi Polytechnic, Rumuola, P. M. B. 5936, Port Harcourt, Rivers State, Nigeria
Department of Microbiology, Faculty of Science, University of Port Harcourt, P. M. B. 5323, Port Harcourt, Rivers State, Nigeria.
sololeera@yahoo.com

Abstract: Fungi play an important role in addressing major global challenges. Use of fungal processes and products can lead to increased sustainability through more efficient use of natural resources. Fungi are used in many industrial fermentative processes, such as the production of vitamins, pigments, lipids, glycolipids, polysaccharides and polyhydric alcohols. They possess antimicrobial activities and are used in biomineralization, as a food for its high protein contents and as a biofertilizers. Fungi are extremely useful in making mycoproteins and acts as plant growth promoters and disease suppressor. Common examples of fungi are *Penicillium* sp, *Mucor* sp., *Rhizopus* sp., *Fusarium* sp., *Cladosporium* sp., *Aspergillus* sp. and *Trichoderma* sp. Fungi are used as food sources in the preparation of leavened bread and fermented juices (*Saccharomyces crevisiae*). Fungal biotechnology is a major participant in the global industry due to its mind blowing potential. In the new bioeconomy, fungi play a very important role in addressing major global challenges, being instrumental for improved resource efficiency, making renewable substitutes for products from fossil resources, upgrading waste streams to valuable food and feed ingredients, counteracting life-style diseases and antibiotic resistance through strengthening the gut biota, making crop plants more robust to survive climate change conditions, and functioning as host organisms for production of new biological drugs. The paper, seeks to examine the importance of fungi in the petroleum, agro-allied, Agriculture and pharmaceutical industries.
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1. Introduction

Fungi are eukaryotic organisms which generally reproduce sexually and asexually and have characteristic rigid cell wall containing chitin or cellulose or both (Jůzlová *et al.,*1996). They are osmotrophic chemoheterotrophs which collectively utilize substrates ranging from simple sugars to complex carbohydrates. Although fungi are typically aerobic, some are facultative or obligate anaerobes. They produce extracellular enzymes (including cellulases, xylanases and pectinases) which release soluble components from insoluble materials. Fungi include hundreds of species which are of tremendous economic importance to man. In fact our lives are intimately linked with those of fungi. Hardly a day passes when we are not benefited or harmed directly or indirectly by these organisms (Alexopoulos *et al.,* 1996).

The English word *fungus* is directly adopted from the Latin *fungus* (mushroom). The word *mycology*, derived from the Greek *mykes* (mushroom) and *logos* (discourse), is used to denote the scientific study of fungi. Fungi have a worldwide distribution, and grow in a wide range of habitats, including extreme environments. A group of all the fungi present in a particular area or geographic region is known as mycobiota. Around 120,000 species of fungi have been described by taxonomists. They play an important role in medicine yielding antibiotics, in agriculture by maintaining the fertility of the soil and causing crop and fruit diseases, forming basis of many industries and as important means of food. Some of the fungi are important research tools in the study of fundamental biological processes. Some of these fungi, particularly mold and yeasts, play a negative role by causing spoilage of stored goods such as foodstuffs, textiles, leather, rubber, plastic, timber and even glass (Bennet, 1996; Benka-Coker and Olumagin, 1996). They are used also as sources of antibiotics and industrially important chemicals (e.g., alcohols, acetone and enzymes) as well as for their role in fermentation processes (e.g., the production of alcoholic beverages, vinegar, cheese and bread dough). The fungi form the basis of many important industries.

The shift from chemical processes to biological processing, achieved by using fungal enzymes instead of chemical processes in industries, such as textiles, leather, paper and pulp, has significantly reduced negative impacts on the environment. Use of enzymes in the food and feed industry, such as animal feed, baking, brewing, and wine and juice, has significantly improved what we get out of biological raw materials. Microbial enzymes added to detergents, washing laundry clean even at low temperatures, has significantly reduced CO2 emissions. There are a number of industrial processes in which the biochemical activities of certain fungi are harnessed to good account. Fungi play an important role in addressing major global challenges. Use of fungal processes and products can lead to increased sustainability through more efficient use of natural resources. Applications range from upgrading bio-waste for value added products to use of renewable plant biomass as a substitute for oil-based products such as biochemicals, plastics, fertilizer, and fuel. Fungal inoculum, introduced into soil together with seed, can promote more robust plant growth through increasing plant uptake of nutrients and water, a robustness of importance for maintaining crop yields under climate change condition. Fungal enzymes can lead to production of food ingredients with prebiotic effects for a healthier human gut biota and hence greater resilience towards life-style diseases. Similarly, use of fungi can be a short cut to healthier animal feed and less use of antibiotics in, for example, meat production, one of the current prime sources of multiple drug resistant bacteria. Fungi are one of nature´s most promising hotspots for finding new drug candidates and antimicrobials. Last but not least, fungi have interesting potential as the new way of manufacturing biological medicines and a wide spectrum of new value added bio-based products. The paper, therefore, examine the potential application of fungi in the petroleum, agro-allied and pharmaceutical industries.

1.1 Role of Fungi in the Petroleum Industries

The petroleum industry, also known as the oil industry or the oil patch, includes the global processes of exploration, extraction, refining, transporting (often by oil tankers and pipelines) and marketing of petroleum products (Demain *et al.,* 2004). In the future, when complex organic substrates are to be broken down to complex products to solve challenging problems, fungal and microbial consortia could provide a short-cut to a solution. *Onygena* species, Non-pathogenic species of *Onygenales*, are specialized in breaking down the keratin found in feather, hooves, and horn. The keratin is composed of proteins, bound in a non-bio-accessible form. Among the large number of different proteases produced by *O. corvina*, we discovered that just three enzymes, belonging to two types of protease families, are sufficient to breakdown both feather and pig bristles.

The decomposition of substances by biological systems is known as biodegradation. The conversion of original substances into new products which, in most cases, do not have the same properties as the first product is known as primary biodegradation while the complete conversion of original substance into carbon (IV) oxide, water, and new microbial biomass through simple mineralization is called ultimate biodegradation. Bioremediation is the environmental application of biotechnology and is defined as the use of biological agents or organisms to breakdown pollutants in the environment by the process of biodegradation (Elshafie, 2007).

It is a means of cleaning-up contaminated environments by exploiting the diverse biodegradation abilities of microorganisms to convert contaminant compound of concern to harmless products by mineralization which in turns lead to the generation of carbon (IV) oxide and water or by conversion into microbial biomass (cell materials). Different strains of soil fungi including *Graphium, Fusarium, Penicillium, Paecilomyces, Acremoniun, Mortierella, Giiocladium, Trichoderma* and *Sphaeropsidales* are found to be important groups capable of utilizing petroleum hydrocarbons. Some vital roles of fungi species in the petroleum industries are given in Table 1.

Table 1: Petroleum hydrocarbons degradation by different species of filamentous fungi

Fungi	Compound
Trichoderma harzianum	Naphthalene
Aspergillus spp.	Crude oil
Cunninghamella elegans	Phenanthrene
Aspergillus niger	n-hexadecane
Cunninghamella elegans	Pyrene
Aspergillus ochraceus	Benzo [a] pyrene
Penicillium spp.	Crude oil

1.1.1 Biodegradation of pesticides/ toxic chemicals and petroleum: White Rot fungi have the potential role in degradation of toxic pesticides like DDT, PCB and Lindane. In addition to this, it can degrade certain toxic chemicals like dioxin, benzopyrene, cyanides, azides, CCl_4 and Pentachlorophenol (PCP). *Aspergillus*, *Penicillium*, *Paecilomyces* and *Fusarium* has found to be involved in petroleum degradation at 30 ^oC in contaminated soil environment.

1.1.2 Biodegradation of Azo dye and hydrocarbons: Peroxidase enzyme of *Penicillium crysosporium* and *Streptomyces* spp. have potential biodegradable activities that degrade Amaranth dye, Orange G, heterocyclic dyes like, Azure B and Lip dye. The filamentous fungi are also having role in degradation of toxic hydrocarbons.

1.1.3 Fungi in hazardous waste remediation: Fungi help in remediation of explosive contaminated soil by its lignin degrading Enzymes. TNT, RDX, HMX are some of the potential explosives that contaminates soil and water. Other degradable nitro explosives by *Pleurotus ostreatus* are Nitrobenzene, 4-Nitrophenol, 4-Nitroaniline, 1-Methoxy 4 nitrobenzene, 2-Methoxy 4-nitro phenol and 1, 2, di Methoxy 4 nitrobenzene.

1.1.4 Biomineralization of Heavy Metals: The fungi have eminent role in the removal and recovery of heavy metals from wastewater and industrial effluents. Hg, Cu, Ni, Pb, Cd are extracted at pH 2-5 by myceliar beads of Penicillium. The fungi also play the following harmful roles:

1.1.5 Destruction of timber: Several fungi such as Polyporus, Serpula lacrymans, Fusarium negundi, Coniophora cerebella, Lentinus lapidens and Penicillium divaricatum cause destruction of valuable timbers by reducing the mechanical strength of the wood.

1.1.6 Destruction of textiles: Several fungi are able to grow on cotton and woolen textiles causing their destruction. These include species of *Alternaria*, *Penicillum*, *Aspergillus*, *Mucor* and *Fusarium*. spp. of Stachybotrys which causes destruction of cotton in storage houses. *Chaetomium globosum* is reported to cause greatest damage to textiles.

1.1.7 Destruction of Paper: Paper pulp wood is destroyed by the growth of Polyporus adustus, Polystictus hirsutus etc. several fungi such as species of *Chaetomium*, *Aspergillus*, *Stachybotrys*, *Alternaria*, *Fusarium*, *Dematium*, *Mucor* and *Cladosporium* cause extensive damage to industrial materials including papers, books, newspapers and wood industry.

1.1.8 Cellulose degradation by fungi: Heap of agricultural residues, forest residues deposited ample of celluloses in the soil. Only fungal cellulases are involved in degradation of deposited cellulose. *Fusarium*, *Trichoderma*, *Penicillium* derived cellulases are involved in degradation of celluloses. Degradation of these leads maximum bioenergy production. Other fungal enzymes are gluconase and glucosidase (cellobiase).

1.1.9 Bioconversion of lignin: White Rot fungi such as *Coriolus versicolor*, *Polyporus ance* and Brown Rot fungi like *Poria monticola*, *Lenzitis trabea* are used in depolymerization and degradation of lignin to low molecular weight Petroleum products. These fungi are also used in softening of wood in paper making industries.

1.2 Role of Fungi in the Agro-Allied Industries

Different industries that work together in some way, usually by providing goods or a service to other industries or being dependant on another industry (receiving goods or a service) is said to be an Allied industry. Agro-allied industries, therefore, are corporate entities working in full symbiosis operation with the Agricultural industry by providing or deriving goods or a service from Agricultural. The industrial uses of fungi are many and varied. In fact the fungi form the basis of many important industries. There are a number of industrial processes in which the biochemical activities of certain fungi are harnessed to good account. The roles of fungi in the agro-allied industries are as follows:

1.2.1 Alcoholic fermentation: Fungi are widely used in fermentative industries for the production of ethanol, organic acids, antibiotics and enzymes like fungal cellulases, gluconase and glycosidase. *S. cerevisae* and *Monilia* sp. are used in ethanol production. Fungi are also useful industrially in ripening of cheese and processing of other products. It is the basis of two important industries in India or rather all over the world. These are brewing and baking. Both are dependent on the fact that the fermentation of sugar solutions by yeasts produces ethyl alcohol and carbon dioxide. In brewing or wine making industry alcohol is the important product. The other by-product which is carbon dioxide was formerly allowed to escape as a useless thing. Now carbon dioxide is also considered a valuable by-product. It is collected, solidified and sold as “dry ice”. In the baking or bread- making industry CO_2 is the useful product. It serves two purposes: (i) cause the dough to rise, (ii) Makes the bread light. The other by-product, which is alcohol, is incidental. The yeasts secrete the enzyme complex called zymase which brings about conversion of sugar into alcohol. Many excellent yeast strains are now available. The yeasts lack diastase. So they cannot break starch into sugar. There are a number of fungi popularly known as the moulds (Hamlyn, 1997; Bennet, 1998). They secrete a whole range of enzymes and thus bring about fermentation of complex carbohydrates. In producing industrial alcohol moulds are employed as starters to bring about scarification of the starch. At the second stage yeast is employed to act on the sugar. Although mould can complete the conversion to sugar but the yield is better if yeast is employed for the second stage. The moulds commonly used for purpose of scarification are *Mucor racemosus*. *M. rouxii* and some species of *Rhizopus*. *Aspergillus flavus* is used in the production of African native beer.

1.2.2 Enzyme preparations: Takamine on the basis of his intensive study of the enzymes produced by *Aspergillus flavus*-oryzae series has introduced in the market a few products of high enzymic activity. These are Digestin, Polyzime, Taka diastase, etc. They are used for dextrinization of starch and desiring of textiles (Itah *et al.,* 2009). Cultures of *Aspergillus* *niger* and *A. oryzae* on trays of moist, sterile bran yield a well-known amylase which contains two starch splitting components. Invertase is extracted from *Saccharoymces cerevisiae*. It has many industrial uses. It hydrolyses sucrose to a mixture of glucose and fructose.

1.2.3 Preparation of organic acids: The important organic acids produced commercially as the result of the biochemical activities of moulds are oxalic acid, citric acid, gluconic acid, gallic acid, fumaric acid, etc. Oxalic acid is the fermentation product of *Aspergillus niger*. Citric acid is made by mould fermentation. Many species of Penicillium are used for the purpose. The acid is produced on a commercial scale and is cheaper than the acid made from the citrus fruits (Junior *et al.,* 2009). The gluconic acid is prepared from sugars. The moulds chiefly employed for this purpose are some species of *Penicillium* and *Aspergillus*. Gallic acid is prepared on a commercial scale in Europe and America. The details of the method employed, however, are not known. It may be a modification of Calmete's process. Calmette (1902) obtained the gallic acid as the fermentation product of an extract of tannin by *Aspergillus gallomyces*.

1.2.4 Gibberellins: These are plant hormones produced by the fungus *Gibberella fujikuroi* which cause a disease of rice accompanied by abnormal elongation. Gibberellin is used to accelerate growth of several horticultural crops.

1.2.5 Cheese Industry: Certain fungi popularly known as the cheese moulds play an important role in the refining of cheese. They give cheese a characteristic texture and flavour. The two chief kinds of mould refined cheese are: (a) Camembert and Brie types. They are soft and (b) *Roquefort Gorgonzola* and Stilton types. They are green or blue veined cheese. The moulds concerned are *Penicillium camemberti* and *P. caseicolum* in the first type and *P. roqueforti* in the second type.

1.2.6 Manufacture of Proteins: As a supplement to the normal diet, some fungi particularly the yeasts are employed to synthesize proteins. The yeast (*Saccharomyces cerevisiae* and *Candida utilis*) contain high percentage of protein of great nutritive value. They are grown with ammonia as the source of nitrogen and molasses as the source of carbon. The manufactured product is called Food Yeast. It contains 15 % protein and B group of vitamins.

1.2.7 Vitamins: The yeasts are the best source of vitamin B complex. A number of preparations of high potency have been made from the dried yeast or yeast extracts and sold in the market. A number of moulds and yeasts are utilized in the synthesis of Ergosterol which contains Vitamin D. Riboflavin—another vitamin useful both in human and animal food—is obtained from a filamentous yeast, *Ashby gossypii*.

1.2.8 A good many fungi synthesize fat from carbohydrates: *Endomyces vernalis*, *Penicillium javanicum* and *Oidium lactis* have a high fat content. The microbiological production of fat is, however, too costly for use.

1.2.9 Designing of vectors: Recombinant DNA technology, which includes yeasts and other fungi as hosts, has markedly increased market for microbial enzymes. Yeast vectors are used in genetic engineering. E.g., shuttle vectors are used for expression of desirable gene in both prokaryotic and eukaryotic systems. YAC, YRP, YIP, YEP are some other yeast vectors.

1.2.10 Food Producers: The fungi are also important as producers of foodstuffs. Certain species of Penicillium are active in the refining of certain kind of cheeses. Some fungi, such as red bread mold, *Neurospora sitophila* and others, complete their sexual life cycle in a few days and thus make ideal organisms for the study of the laws of heredity.

1.2.11 Fungi as Food: Many species of fungi are edible, about 2000 species of them have been reported from all over the world. Of these, about 200 are said to occur in the Western Himalayas. Many edible fungi are of great economic value as food. They are regarded as delicacies of the table. There are said to be over 200 species of edible fungi. The specialized basidiomycete *Termitomyces titanicus* (*Agaricales*) grows in subterranean termite nests. It can grow to form massive and impressive basidiomes, used as a human delicacy (Table 2). The benefit to the termites – even without having developed the sophisticated farming procedure – is accessibility to protein rich feed. The percentages of protein in edible basidiomycetous fungi are high (measured as % of total dry weight; an extraordinarily high protein content has been recorded for *Termitomyces* species. In future we will be able to make biorefineries by growing fungi on household waste and use the protein rich fungal biomass for animal feed. The fructifications of some fungi such as the field mushroom *Agaricus campestris* (dhingri), *Podaxon podaxis* (Khumb), the honey coloured mushrooms, the fairy ring mushrooms, the puff balls (Lycoperdon and Clavatia), morels (Morchella, guchhi), and truffles are edible. The content of available food in them is not high but they supply vitamins and are valuable as appetisers. Yeasts and some filamentous fungi are valuable sources of vitamins of the B-complex. A few of the mushrooms are fatally poisonous, some cause only discomfort. To the former category belongs to the Amanita. Fungi are used as high cost food because of its high protein and low calorific value. Europe, America, Australia and Japan are very playing industries in mushroom cultivation. Some examples of edible fungi are *Agaricus compestris,* Volvariella (paddy straw mushroom), Morchella (Temperate zone mushroom), *Pleurotus* sp. (oyster mushroom) and *Agaricus bisporus* (white button mushroom).

Table 1: Basidiomes used as a human delicacy

Fungi species	**Protein (% DW)**
Button mushroom (*Ogaricus bisporus*)	35.7
Oyster hat (*Pleurotus ostratus*)	27.7
Chantharellus cibarus	22.3
Chicken mushroom (*Termitomyces* sp.)	30.1-48.0

1.2.12 Fungi in improving the quality of produce: It is evidence that some fungal diseases can enhance the nutritional quality of food and feed. E.g. smutted corn and rust infected wheat grains have more carbohydrate and phosphorus contents as compare to healthy plants.

1.2.13 Fungi as biofertilizes: Vesicular arbuscular mycorrhizae are the mutualistic symbiosis between the roots of higher plants and certain fungi. The mycorrhizae help in the phosphate nutrition of plants and protect the roots by forming the mantle.

1.2.14 Fungi as 'Microbial weed killer' (Bioherbicides): Fungi are known for its quite specific and effective action and have low residual effects in comparison with synthetic pesticides. Here are given some fungi as bioherbicides. Fungi are used as bioherbicides. Some examples with their targets are given in brackets. These are *Septagloeum gillis* (Mistletoes), *Wallrothiella arecuthobii* (Mistletoes), *Colletotrichum gloeosporiordes* (Mistletoes), Phyllosticta (Glycosmis), *Leptosphaerulina trifolia* (Passiflora), *Puccinia chondrillina* (Rush weed) and *Cercospora ageratinae* (Pamakani weed).

1.2.15 Spoilage of food stuffs: Many fungi are responsible for spoilage of food stuffs. *Penicillium digitatum* causes rotting of citrus fruits. Milk and milk products are spoiled and made unfit for human use due to the growth of several fungi such as *Mucor*, *Aspergillus*, *Penicillium*, *Oidium* and *Fusarium. Mucor mucedo* and spp. of *Aspergillus* grow on bread and spoil it. *Oidium lactis* develops the fishy odour of butter causing damage to the butter. In tropical conditions, many fungi such as *Mucor* sp., *Penicillium*, *Neurospora*, *Fusarium* and *Aspergillus*, grow on meat causing sufficient spoilage. Aflatoxins the most potent carcinogenic agent-are produced by *Aspergillus flavus*, *A. fumigatus*, *A. parasiticus* and *Penicillium islandicum* on dried foods and groundnut meal. Aflatoxins are reported to bind with DNA and prevent its transcription arresting protein synthesis. These are responsible for liver cancer in animals and human beings. Mushroom toxins are produced by several poisonous mushrooms. These cause diarrhoea vomiting, liver damage, complete unconsciousness etc. Mushroom toxins are commonly produced by *Amanita phalloides* of Helvella and some species of Inocybe. Ergot toxins produced by *Claviceps purpurea* contain poisonous alkaloids like ergotamine, ergometrimine, ergocrystinine, ergocrystinine and ergonovin. These cause diarrhoea, abdominal pain, vomiting and psychiatric disturbances. An Entamopathogenic fungus secretes the toxin, which possesses the entemocidal properties. The pathogenic fungi are always a nuisance to the agriculturists. They affect the agricultural economy of our country seriously. The slime molds (*Physarum polycephalum*) are now widely used in research. P. polycephalum has proved an excellent experimental organism for the study of DNA synthesis, meiotic cycle and the mechanism of protoplasmic streaming. Fungi used as the rich sources of Single Cell Proteins (SCP) are *Saccharomyces cerevisae* (Yeast), *Aspergillus niger, Penicillium chrysogenum, Fusarium avenacum* and *Neurospora sitoplila.*

1.3 Role of Fungi in Agriculture Industries

1.3.1 Negative Role

They have a negative value because they are the causative agents of different diseases of our crop, fruit and other economic plants. These fungal diseases take a heavy toll and cause tremendous economic losses. The modest estimate is that about 30 thousand different diseases (including bacterial and virus) attack the economic plants grown for food or commercial purposes. The more important of these diseases include the following:

a. Damping off disease: The seedlings of almost every type of plant grown as a commercial crop such as tomatoes, com, cotton, mustard, peas, beans, tobacco, spinach, etc., are prone to this disease. It is caused by a species of *Pythium*.

b. The potato blight: Late blight of potatoes is another destructive crop disease. It does a great damage to the potato tubers. A heavy attack of this disease in Ireland in 1845 destroyed the entire potato crop and caused so severe a famine that over a million Irish people migrated to U.S.A. Besides potatoes, it infects egg plants and tomatoes.

c. Downy mildews of grapes: It ruins the vine yards and thus causes heavy losses to the crop. When the disease was first introduced into France from U.S.A, it caused havoc to the vine yards. Almost all the French vine yards were destroyed before Bordeaux mixture, which proved an effective fungicide against this disease, was discovered.

d. Ergot disease of rye: It is an important disease of a cereal crop—rye. It results in the formation of poisonous sclerotia in the rye kernel. It is called ergot of rye. Ergot is highly poisonous to man. Ergot poisoning causes hallucinations, insanity and finally death.

e. Apple scab: It is a serious disease of the apple crop. It lowers the quality as well as quantity of the fruit.

f. Brown rot of stone fruits: It causes enormous losses in the fruit crop of apricots, cherries, plums and peaches.

g. Smut diseases: Smut diseases of corn, wheat, oat and other cereal crops cause serious reduction in the yield and quality of grain.

h. Red rot disease of sugarcane: It is a serious disease of sugarcane whose incidence has increased during the last few years, particularly in the northern parts of the country.

i. Rust diseases: They attack our cereal crops and forest timber. Some of them such as black stem rust, yellow rust and orange rust are a serious threat to our wheat crop.

j. Blackarm, Wilt and root rot of cotton: These diseases of cotton, which is a very important commercial crop of our country, take a heavy toll of the crop every year.

k. Pore fungi: They are the common wood rotters. They destroy timber and lumbar.

1.3.2 Positive Role

Some soil fungi are beneficial to agriculture because they maintain the fertility of the soil. Some saprophytic fungi particularly in acid soils where bacterial activity is at its minimum cause decay and decomposition of dead bodies of plants and their wastes taking up the complex organic compounds (cellulose and lignin) by secreting enzymes. The enzymes convert the fatty carbohydrate and nitrogenous constituents into simpler compounds such as carbon dioxide, water, ammonia and hydrogen sulphide. Some of these return to the soil to form humus and the rest of the air from where they can again be used as raw material for food synthesis. Besides, many saprophytic fungi of decay maintain the never ending cycle of carbon dioxide which is a most important raw material for plant photosynthesis in nature. They also bring about rot, decay and decomposition of animal and plant remains releasing plant nutrients in a form available to green plants as food. The soil fungi utilize many inorganic salts. These are prevented from being lost from the soil by leaching. Some fungi form mycorrhizal association with the roots of certain plants and help them in their nutrition. Such plants will grow satisfactorily only when the mycelium of the appropriate fungal partner is present in the soil (Manzoni *et al.,* 1999). The fertile soil contains twice as much living fungus cell material as the material from bacteria and other soil microorganisms. Giberrrelin produced by *Gibberella fujikuroi* is used as growth hormone accelerating plant growth. Many insect pests can be controlled by the growth of fungi such as *Empusa sepulchrasis*, *Metarrhizium anisopliae* and *Cordyceps melothac*. Some common fungal inhabitants of the soil help to combat diseases caused by soil borne fungi. *Trichoderma lignorum* and *Gliocladium fimbriatum* are found in damp soils. They have an inhibitory effect on the growth of the mycelium of *Pythium*. They serve to suppress fungi causing the damping off disease of the seedlings and thereby influence favourably the growth of crops.

1.4 Role of Fungi in the Pharmaceutical Industries

1.4.1 Antibiotic production: The role of fungi in producing antibiotic substances was first established by Sir Alexander Fleming in 1929. Penicillin is an organic substance lethal to microbes. Penicillin is made from a fungus of the genus *Penicillium*, a green mildew, belonging to deuteromycetes. *Penicillium notatum*, *P. crysogenum* and *Cenococcum* sp. are used in antibiotics production. An ascomycete, *Giberella fujikuroi*, can secrete a plant-growth hormone known as gibberellin. Fungi have recently helped to produce innovative and important drugs, such as cyclosporin, an anti-rejection substance that has aided the development of organ-transplant surgery over the last few years. The term antibiotic denotes an organic substance, produced by a microorganism, which inhibits the growth of certain other microorganisms. Penicillin is now produced on a commercial scale all over the world including India from the improved strains of *P. notatum* and *P. chrysogenum*. Streptomycin is obtained from *Streptomyces griseus*. It is of great value in medicine. It destroys many organisms which are not killed by penicillin particularly the gram-negative organisms. A numbers of antibiotics have also been extracted from *Aspergillus* cultures. However, these have not been proved as effective as penicillin. Some of the actinomycetes which are not considered to be true filamentous bacteria are the sources of many antibiotics such as chloromycetin, aureomycin, terramycin, etc. They inhibit the growth of many pathogenic bacteria and are also used successfully in the treatment of various virus diseases. Many animal and human diseases which do not respond readily to other antibiotics are effectively cured by aureomycin. The plasmodia of certain species of Myxogastres have been reported to yield soluble antibiotics. These check the growth of certain bacteria and yeasts in culture. The antibiotics play an important role to combat plant diseases as well. Certain fungi form an important basis of fermentation of Cocaobeans. Mention must also be made here of the use of Lichens in yielding certain dyes and reagents. An important substance is extracted from Roccella lichen. It forms the basis of litmus paper which is used as an indicator to determine the acidity or alkalinity of a solution. Griseofulvin which is recovered from mycelium of *Penicillium griseofulvum* and many other species has antifungal properties. It acts on the hyphae by interfering with wall formation. Consequently the hyphal tips curl and cease to grow. When administered orally it is absorbed into the body where it accumulates in the keratinized tissues of the epidermis and hair. It is thus effective against fungal skin diseases such as ringworms and athlete's foot disease. *Claviceps purpurea* produces sclerotia in the ovaries of the flowers of grasses such as rye. The sclerotium is called the ergot of rye. Ergot is used in veterinary and human medicine. It contains a mixture of alkaloids which cause rapid and powerful contractions of the uterus. The medicine is thus used to control bleeding during child birth. Ergot is highly poisonous. A derivative of ergot known by the name of lysergic acid is used in experimental psychiatry. The giant puff ball Clavatia contains an anti-cancer substance calvacin. The eating of these fungi prevents stomach tumours.

1.4.2 Secondary metabolites: *Aspergillus nidulans* are used for isolation of secondary metabolites. The secondary metabolites are used as drug. Ergot alkaloids (Ergometrin and Ergotoin) and Lovastatin, a popular cholesterol-lowering drug are the secondary metabolites. Fungal metabolites have antitumour, antiviral, antibacterial and immunosuppressants activities.

1.4.3 Root nibblers: Fungal pathogens are use as root nibblers to produce many root fibers that increase the maximum uptake of nutrients and water for more yields. *Trichoderma viridae* and *fusarium* spp. has shown increased number of root fibres in Tomato and Maize plants respectively.

1.5 Why Fungi in the Petroleum, Agro-Allied, Agriculture and Pharmaceutical Industries?

During the last two decades, the fungi have been used to test various biological processes. Since they grow very fast and require a short period to complete their life cycles, the fungi are best suited for use as test organisms. Fungi form very good research material for genetical studies and other biological processes Genus *Neurospora* has become very good material for genetic studies while *Physarum polycephalum* is used to study steps in DNA synthesis, morphogenesis and mitotic cycle. To detect the presence and quantity of vitamin B in given sample, *Neurospora crassa* is commonly used. Similarly *Aspergillus niger* is used for detection of trace elements like zinc, nickel and copper even when they are present in very minute quantities. There are numerous reasons for using fungi in the industries (Nevalainen *et al.,* 2005). The ease of transportation, genetic engineering and scaling-up to produce required quantities as is popular in yeasts and *Penicillium* strains in the fermentation industry makes fungi organisms of choice in bioremediation of oil-polluted environments. Fungal extensive mycelia penetrate insoluble substrates such as oil and this increases the surface area available for petroleum hydrocarbon biodegradation. Fungi are notably aerobic and can also grow under environmentally stressed conditions such as low pH and poor nutrient status where bacteria growth might be limited. Although bacteria initiate the degradation of synthetic petroleum mixture, twice as much is degraded when a mixture of bacteria, moulds, and yeasts are utilized. Fungi have through the ages evolved special traits to degrade hydrocarbons. These special traits include (i) Petroleum-degrading microorganisms have special traits of efficient hydrocarbon up-take, that is, special receptor sites for binding hydrocarbons and/or the production of unique chemical substances that assist in the emulsification and transport of hydrocarbons into the cell, (ii) They have group-specific oxygenases, that is, enzymes which introduce molecular oxygen into the hydrocarbon and with relatively few reactions generate intermediates that subsequently enter common energy-yielding catabolic pathways and (iii) Inducer specificity, that is, positive response of the microorganisms to petroleum and its constituents in inducing the first two systems above. Fungi that have the ability to utilize hydrocarbons occurred mainly in two orders, the *Mucorales* and the *Monilales.*

1.6 Summary and Conclusion

The time is right to make the world aware of the immense importance of fungi and mycology for sustainable global development, where land, water and biological materials are used in a more efficient *and* more sustainable manner. This is an opportunity for profiling mycology by narrating the role played by fungi in the bio-economy. Greater awareness and appreciation of the role of fungi can be used to build support for mycology around the world. Support will attract more talent to our field of study, empower mycologists around the world to generate more funds for necessary basic research, and strengthen the global mycology network. The use of fungi for unlocking the full potentials of the bio-economy relies on such progress. The fungal kingdom can be an inspiration for even more. The right antimicrobial agents are widely used in the various industries to control microbial contamination of products and equipment. The time is right to make the world aware of the immense importance of fungi and mycology for sustainable global industrial development, where land, water and biological materials are used in a more efficient and more sustainable manner. This is an opportunity for profiling mycology by narrating the role played by fungi in the various industries and bio-economy. Greater awareness and appreciation of the role of fungi can be used to build support for mycology around the world. Support will attract more talent to the field of study; empower mycologists around the world to generate more funds for necessary basic research and strengthen the global mycology network. The use of fungi for unlocking the full potentials of the petroleum, agro-allied and pharmaceutical industries relies on such progress. The potential of fungi organisms for more sustainable world must be released to address global challenges of climate change, higher demands on natural resources and the increased burden of lifestyle diseases.

1.7 Recommendations

There is need to stimulate mycology globally and work more efficiently together to take good care of this diversity and unlock the full potential of the fungal kingdom for future use all over the world. The discipline of mycology needs to be developed to a stage where it can recruit talent for the new generation of mycological researchers and for building the skills needed for the world to change towards the new and more sustainable bio-economy. Increased understanding of the fungal kingdom, phylogeny and phylogenomics as a basis for understanding the fungal life-form generally and for expanding the exploitation of fungal biodiversity for more value added uses; the *mycological platform*, building mycological know how and skills in all parts of the world are of significance.

Corresponding Author:
Dr. Leera Solomon
Department of Science Laboratory Technology, School of Science and Technology, Captain Elechi Amadi Polytechnic, Rumuola, P. M. B. 5936, Port Harcourt, Rivers State, Nigeria
E-mail: sololeera@yahoo.com

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