



## Nigerian Mushrooms: Underutilized Non-Wood Forest Resources

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**ABSTRACT:** Mushroom resources have been exploited in most developed economies because of their huge agro-industrial, medicinal and commercial benefits. Nigerians utilized mushroom-forming fungi only for food and folk medicine for many decades. *Auricularia auricular* Judae (Bull.) Quél, *Lentinus squarrosulus* Mont., *Pleurotus tuberregium* (Fr.) Singer and *Volvariella volvacea* (Bull.) Singer was some of the common edible mushrooms that were successfully cultivated in Nigeria on small-scale basis. The mushroom resources in Nigeria are grossly under-studied and their attractive potentials under-exploited for addressing economic and industrial development. Resourceful biotechnological approach in the application of mushrooms in agriculture, medicine, industry and environment is inchoate and uncommon in the country. @ JASEM

Mushrooms are widespread in nature and they remained the earliest form of fungi known to mankind. In Nigeria, many people in both urban and rural areas are familiar with mushroom-forming fungi growing around them some of which they exploit for food and medicine. This practice although reported all-over the country is more pronounced amongst the Yoruba speaking people (Alabi, 1991). Concomitant varieties of mushrooms i.e. lichenized, mycorrhizal, parasitic and saprotrophic that abound in Nigeria have continued to gain recognition and elicit different interests and questions as potentially resourceful tool in economic modulation *pari passu* prevailing reliance on leafy plants. It is saddening to see that people from all works of life associate mushrooms with negative events in Nigeria and most African countries (Yongabi et al., 2004; Akpaja et al., 2005). This image, in addition to the slow development of mushroom cultivation practices is changing due to reports elsewhere in the world that illuminate potentials of mushroom-forming fungi and mushroom products and their uses in different spheres of human welfare (Wainwright, 1992; Robert and Hajek, 1993; Wasser, 2007). This is apart from their hitherto pivotal roles in sustaining eco-energy balance in nature (Jumpponen et al., 2004).

In Africa, mushroom resource exploration and exploitation is fraught with lack of infrastructure and technical supports from national and international agencies, scarcity of mushroom scientists, poor political and legislative support, poor knowledge of mushroom biodiversity due to dearth of mushroom taxonomists and bad press reports amongst others (Laberere and Menini, 2000). Reports on Nigerian mushrooms such as Ogundana (1975), Oso (1975 and 1977) and Zoberi (1973) are old and currently an under-representation of Nigerian mushroom's diversity, composition and uses. African nations are seldom listed among the largest producers and exporters of

edible mushrooms and mushroom products (Chang and Miles, 1991; Flegg, 1992).

The objective of this paper therefore, is to review the mushroom research-application divides in Nigeria against the flux of unprecedented global reports on mushroom potentials, explorations and exploitations for human benefits. This illuminated the need to prospect mushrooms and shift focus from reliance on plant genetic resources to mycotas as better alternative in addressing Nigeria's economic and technological development by reviewing existing mushroom articles on Nigeria.

*Mycophagy:* A good number of mushrooms have been reported by Akpaja et al., (2003, 2005), Osemwegie et al. (2006), Gbolagade et al. (2006) to be consumed by different tribal groups in Nigeria. People depending on their tribe slightly differ in the array of mushrooms consumed and reasons for their consumption (Oso, 1975). The Yoruba tribes however recorded the highest number of edible and medicinal mushrooms compared to the Hausa tribes (Table 1). The reason for this trend is not fully understood but it is believed to be connected to the relatively few accounts of edible, medicinal and cultivable mushrooms in extant literature. Factors such as the arid nature of the North occasioned by desert encroachment; scarcity of mushroom biologists and mushroom interest; availability of alternative protein sources may have contributed to the scarcity of mushroom information on the Hausas (Idu et al., 2007). Many culturally varied mycophagists are ignorant of the nutritional values of edible mushrooms but consume them based on their organoleptic property such as aroma, taste, flavour, and texture (Ene-Obong and Camovale, 1992; Osemwegie et al., 2006). Other reasons reported for mycophagy in Nigeria are subsumed in their local names e.g. *Volvariella volvacea* (Bull.) Singer is referred to by the Yoruba people as "ogiri agbe" meaning farmer's spice (Oso, 1975) while *Lentinus* sp is called "Ero atakata" by the Igbo

speaking people, a name derived from its tough texture (Akpaja *et al.*, 2003). Studies on the nutritional values of edible and medicinal mushrooms ranked them with dairy, plant and animal food in vitamins, protein and mineral contents. This has however failed to neither improve mycophagy culture in urban cities in Nigeria nor promote the commercial productions of mushrooms (Ene-Obong and Camovale, 1992; Adewusi *et al.*, 1993; Aletor, 1995). The most popular edible mushroom in Nigeria is the sclerotium-forming *Pleurotus tuberregium* (Fr.) Singer which is eaten as food and/or used as food supplement (Gbolagade *et al.*, 2006). The sporophore is used as a good substitute for meat protein in several suburban Nigerian soups by locals (Ene-Obong and Camovale, 1992). Its popularity as food in many rural villages especially in the south zone of the country is ascribed to its substrate propensity, rapid growth, fruit-body longevity, incidences and distribution pattern (Zoberi, 1973; Osemwegie *et al.*, 2006). Other edible mushrooms consumed in Nigeria include *Agaricus* spp., *Auricularia auricular* Judae (Bull.) Quél., *Collybia butyracea* (Bull.) P. Kumm., *Coprinus atramentarius* (Bull.) Fr., *Coprinus picaceus* (Bull.) Gray, *Lactarius trivialis* Fr., *Lentinus squarrosulus* Mont., *Pleurotus pulmonarius* (Fr.) Quél., *Pleurotus ostreatus* Jacq., *Macrolepiota* sp., *Psathyrella atroumbonata* Pegler, *Schizophyllum commune* Fr., *Termitomyces clypeatus* Heim., *Termitomyces globules* Heim & Gooss, *Termitomyces mammiformis* Heim., *Termitomyces microcarpus* (Berk. & Br.) Heim, *Termitomyces robustus* (Beeli.) Heim, *Tricholoma* sp., *Volvariella volvacea* (Bull.) Singer and *Volvariella esculenta* (Mass.) Singer (Fig. 2 and Table 1). *Amanita* mushrooms which were labeled poisonous in many parts of the world have been reported in Nigeria by Zoberi (1973) and elsewhere in Africa (Morris, 1990) to have species that are consumed as food. In the same vein, *Chlorophyllum molybdites* also featured amongst edible mushrooms analyzed for their nutrient contents in Nigerian and considered safe for consumption (Fasidi and Kadiri, 1995; Aletor and Aladetimi, 1995). The edibility *Amanita* and *Chlorophyllum* species earlier reported as poisonous elsewhere in the world by Nigerians is not totally understood but it is believed that the controversy may stem from any one or combination of factors relating to environment, genetic and physiological differences which were determinants of tolerance level to toxins amongst racially, geographically and traditional varied people. The method of preparation of these mushrooms, insufficient expert taxonomist and/or poor identification method coupled with the use of monographic/taxonomic books on western mushroom taxa for naming indigenous African macrofungi may also have been responsible for this contention (Osemwegie and Okhuoya, 2009).

Regular and professional myco-systematic molecular-based approach coupled with frequent revised documentations of mushroom-forming fungi may resolve further the confusions associated with edible and poisonous mushrooms.

In Nigeria, a great quantity and variety of edible and medicinal mushrooms are sourced from the wild due to inchoate mushroom farming culture. This practice (mushroom scouting/hunting) existed for decades spanning generations and mostly embarked upon by children and women (Okhuoya, 1997). About twenty-five edible mushroom species of good repute whose knowledge were handed down generational lines via oral communication have been identified in Nigeria (Labarere and Menini, 2000). Osemwegie *et al.* (2006) stated that edible mushrooms collected from various farmlands, forests and plantations may be sold or cooked fresh, after treatment with warm salt water, with the addition of essential ingredients like pulped pepper, tomatoes, onions, salt and oil or smoked and/or sun-dried for later use. The reliance on naturally growing edible mushrooms has greatly undermined the development of mushroom cultivation to a commercial scale despite available substrate materials in some African nations. Some of the substrate materials of diverse origin tested in the artificial cultivation of mushrooms in Nigeria are outlined in (Table 3). Despite the fact that about 20% of the world's population was reported by Labarere and Menini (2000) as starving, African nations are still lacking amongst the mushroom exporting nations of the world. Tapping into the benefits of commercial mushroom production in Nigeria will reduce the country's unemployment rate, increase her food security and revenue base while bridging her rural-urban mycophagy gap.

The number of cultivable edible mushrooms worldwide amounts to over a hundred with an annual production of over 4.5 million tons and still increasing (Flegg, 1992; Labarere and Menini, 2000; Mshigeni, 2005). The provision of safe sustainable access to edible and medicinal mushrooms in Nigeria can be achieved in a number of ways which may include (i) by promoting opportunities for co-operation between all stakeholders such as the mushroom farmers, researchers/mycologists, politicians and other mushroom prospectors (marketer, NGOs and government agencies on agriculture, youths and women etc.) in the country; (ii) through the creation of public enlightenment initiatives via talk shows on the positive potentials of mushrooms and mushroom products in radio and television programs, monthly newsletter, seminars and workshops. This will remove the negative publicity associated with mushrooms, increase market sources of edible mushrooms, limit the dangers associated with mushroom hunting from the wild and improve awareness on both the nutrient quality and benefits of mushroom consumption; (iii) by developing a model that allows for spawn

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availability to farmers and steady flow and/or exchange of proprietary culture (mother cultures and pure-lines). This is in addition to the cross-fertilization of cultivation technologies between developing and industrial nations, and creation of recognized indigenous mushroom growers association. The establishment of sustainable regional mushroom germplasm banks and research centers to maintain mushroom genetic stability, quality control of mushroom culture collections and spawn, and preservation of cultures of extant and extinct mycoresources can also enhance the overall uses of mushrooms in the country. One cannot but add that the elevation of mushrooms to a cash-crop status in Nigeria requires improved political will and solid infrastructural (steady electricity, flowing water, buildings etc.) setting. These will have unprecedented impact on the development of the country's mushroom industries in providing food, drugs and chemicals. It will equally offer opportunity for conservation strategies and preservation of mushrooms that will add value to medicine, pharmacy, industries and agriculture.

Despite the high level of progress made through the Global Network on Mushroom Research and Development under the aegis of F.A.O and the advancement of mushroom cultivation industries in many developed nations, growing mushrooms in homes or even on a commercial scale is still uncommon in Nigeria. Researchers are therefore challenged to reduce dependence on naturally occurring mushrooms, the incidences of mushroom poisoning and expand the nation's edible and medicinal mushroom base. Many indigenous edible mushrooms heritage and knowledge may have escaped recognition and documentation and/or completely lost over the years. Although, few works such as such as Akpaja et al. (2003, 2005), Okhuoya and Akpaja (2005) and Osemwegie et al. (2006), a long-term study on the ethnomycological, taxonomic and myco-diversity profile of indigenous mushroom resources on a national scale will form the inertia for mushroom prospecting initiatives and successful exploitation in developmental economic issues in Nigeria. Some of the wild mushrooms occurring in Nigeria are presented in Fig. 2.

**Table 1:** Summary of some edible and medicinal mushrooms and their distribution in Nigeria.

Mushroom	Yoruba(West)	Igbo (East)	Hausa (North)
<i>Auricularia auricular</i> Judae (Bull.) Quél.	+	+	+
<i>Calvatia cyathiformis</i> (Bosc.) Morg.	+	-	+
<i>Chlorophyllum molybditis</i> (Mayer ex. Fr.) Masee	*	+	-
<i>Coprinus picaceus</i> (Bull. ex Fr.) S.F.Gray	-	+	-
<i>Coprinus setulosus</i> Berk. and Br.	+	-	-
<i>Coprinus tramentarius</i> Ulje and Bas.	+	-	-
<i>Cortarius melliolens</i> Fries	+	+	*
<i>Daldinia concentrica</i> (Bolt. ex Fr.) Ces. and DeNot.	*	*	*
<i>Lentinus subnudus</i> Berk	+	+	-
<i>Pleurotus ostreatus</i> Jacq.	+	+	-
<i>Pleurotus pulmonarius</i> (Fr.) Quél	+	-	-
<i>Pleurotus squarrosulus</i> (Mont.) Singer	+	+	+
<i>Pleurotus tuberregium</i> (Fr.) Singer	+	+	+
<i>Psathrella atroumbonata</i> Pegler	+	+	-
<i>Schizophyllum commune</i> Fr.	+	+	*
<i>Termitomyces clypeatus</i> Heim	+	+	+
<i>Termitomyces globules</i> Heim and Gooss	+	+	-
<i>Termitomyces microcarpus</i> (Berk. and Br.) Heim	-	+	-
<i>Termitomyces robustus</i> (Beeli) Heim	+	+	+
<i>Volvariella esculenta</i> (Mass) Singer	+	+	-
<i>Volvariella volvacea</i> (Bull.) Singer	+	-	-

+ = edible, +=edible and medicinal, \*=medicinal, -=uses unknown

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**Table 2:** Some substrates used for cultivation of edible and medicinal mushrooms in Nigeria.

Wastes	Origin/Source	Mushroom	Reference
<b>Farm wastes:</b>			
Rice straw/husk	Rice farms	<i>Pleurotus ostreatus</i> Jacq., <i>P. tuberregium</i> (Fr.) Singer, <i>Volvariella</i> <i>volvacea</i> (Bull.) Singer.	Okhuoya (1997), Ibekwe et al. (2008), Ukoima et al. (2009)
Wheat straw/bran	Wheat farms	<i>Lentinus squarrosulus</i> (Mont.), <i>P. tuberregium</i> (Fr.) Singer.	Okhuoya (1997), Gbolagade (2006)
Corn straw, bracts and cobs	Corn farms, roasted and boiled corn retailers, palp (locally called ogi or akamu) maker.	<i>P. tuberregium</i> (Fr.) Singer, <i>Psathyrella atroumbonata</i> Pegler.	Okhuoya (1997), Ayodele and Okhuoya (2007)
Cassava peelings	Cassava mills/suburbs	<i>P. pulmonarius</i> (Fr.) Quél.	Onuoha et al.(2009)
Plantain/banana leaves, peelings and pseudo stems	Farms, roasted plantain retailers	<i>P. tuberregium</i> (Fr.) Singer	Osemwegie et al. (2002)
Cocoa pod	Farms, local cocoa processing industries	<i>P. ostreatus</i> Jacq.	Alemawor et al. (2009)
Coconut fruit fibre	Farms, industries	<i>Lentinus subnudus</i> Berk, <i>P. tuberregium</i> (Fr.) Singer, <i>V. volvacea</i> (Bull.) Singer.	Okhuoya and Okogbo, (1991), Fasidi and Kadiri (1993), Fasola et al. (2007)
<b>Industrial wastes:</b>			
Cotton wastes	Textile mills	<i>P. pulmonarius</i> (Fr.) Quél	Adebayo et al. (2009)
Sawdust	Saw mills	<i>Psathyrella atroumbonata</i> Pegler, <i>P. tuberregium</i> (Fr.) Singer.	Ayodele and Okhuoya (2007), Okhuoya et al. (1998)
Oil palm fruit fibre and cake	Oil palm mills	<i>P. pulmonarius</i> (Fr.) Quél, <i>Psathyrella atroumbonata</i> Pegler.	Ayodele and Okhuoya (2007), Onuoha et al.(2009)
<b>Domestic wastes:</b>			
Waste papers	Paper mills, printing factory, surrounding.	<i>P. tuberregium</i> (Fr.) Singer.	Osemwegie et al. (2002)

**Table 3:** Some edible and medicinal mushrooms in Nigeria analyzed for toxins, secondary metabolites and other nutritional contents.

Mushroom	nutritional content	Toxin	Secondary metabolites	References
<i>Auricularia auricular</i> Judae (Bull.) Quél.	+	-	-	Aletor (1995), Aletor and Aladetimi (1995)
<i>Calvatia cyathiformis</i> (Bosc.) Morg.	+	-	-	Aletor (1995)
<i>Chlorophyllum molybdites</i> (Mayer ex. Fr.) Massee	-	+	+	Fasidi & Kadiri (1995), Kadiri & Fasidi (1992)
<i>Cortinarius mellioleus</i> Fr.	-	+	+	Kadiri & Fasidi (1992), Fasidi & Kadiri (1995)
<i>Lentinus subnudus</i> Berk.	+	+	-	Kadiri & Fasidi (1992), Aletor (1995), Fasidi & Kadiri (1995), Adejumo & Awosanya (2005)
<i>Lactarius trivialis</i> Fr.	+	-	-	Adejumo & Awosanya (2005)
<i>Pleurotus tuberregium</i> (Fr.) Singer	-	+	+	Kadiri & Fasidi (1992), Fasidi & Kadiri (1995), Adejumo & Awosanya (2005)
<i>Psathyrella atroumbonata</i> Pegler	+	-	-	Aletor (1995)
<i>Schizophyllum commune</i> Fr.	+	-	-	Aletor (1995)
<i>Termitomyces microcarpus</i> (Berk. and Br.) Heim	+	-	-	Aletor (1995)
<i>Termitomyces robustus</i> (Beeli) Heim	+	+	+	Kadiri & Fasidi (1992), Aletor (1995), Fasidi & Kadiri (1995)
<i>Tricholoma lobayense</i> Heim	-	+	-	Kadiri & Fasidi (1992), Fasidi & Kadiri (1995)
<i>Volvariella esculenta</i> (Mass) Singer	-	+	+	Kadiri & Fasidi (1992), Fasidi & Kadiri (1995)

+ = Present; - = Absent

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**Table 4:** Antagonistic potentials of some Nigerian mushrooms against some pathogens.

Mushrooms	Target organisms										References
	<i>Bacillus cereus</i>	<i>Escherichia coli</i>	<i>Klebsiella pneumoniae</i>	<i>Proteus vulgaris</i>	<i>Staphylococcus aureus</i>	<i>Pseudomonas aeruginosa</i>	<i>Aspergillus niger</i>	<i>Chrysosporium keratinophilum</i>	<i>Sclerotium rofskii</i>	<i>Fusarium culmorum</i>	
<i>Auricularia polytricha</i> (Mont.) Sacc.	+	+	-	+	+	-	-	-	-	-	Gbolagade and Fasidi (2005)
<i>Coriopsis occidentalis</i> (Klotzsch) Murr.	+	+	+	+	+	-	+	-	-	-	Gbolagade and Fasidi (2005)
<i>Daedalea elegans</i> Spreng.	+	+	+	+	+	-	-	-	-	-	Gbolagade and Fasidi (2005)
<i>Daldinia concentrica</i> (Bolt.) Ces. & De Not.	+	+	+	+	+	-	-	-	-	-	Gbolagade and Fasidi (2005)
<i>Fomes lignosus</i> (Klotzsch) Bres.	+	+	-	+	+	-	-	-	-	-	Gbolagade et al.(2007)
<i>Marasmius jodocodo</i> Henn.	+	-	+	+	+	-	+	-	-	-	Gbolagade et al.(2007)
<i>Pleurotus tuberregium</i> (Fr.) Sing.	+	+	+	+	+	+	-	+	+	+	Okhuoya et al. (1996), Gbolagade et al.(2007), Badalyan et al. (2008) Gbolagade et al.(2007)
<i>Polyporus giganteus</i> (Pers.) Fr.	+	+	+	-	-	-	+	-	-	-	Gbolagade et al.(2007)
<i>Psathyrella atroumbonata</i> Pegler	+	+	+	+	+	-	+	-	-	-	Gbolagade et al.(2007)
<i>Termitomyces microcarpus</i> (Berk. and Br.) Heim	-	+	-	+	+	-	-	-	-	-	Gbolagade et al.(2007)
<i>Termitomyces robustus</i> (Beeli) Heim	+	+	+	-	+	-	+	-	-	-	Gbolagade et al.(2007)
<i>Tricholoma lobayense</i> Heim	+	+	+	+	+	-	-	-	-	-	Gbolagade and Fasidi (2005)

+ = Antagonistic; - = Non-antagonistic

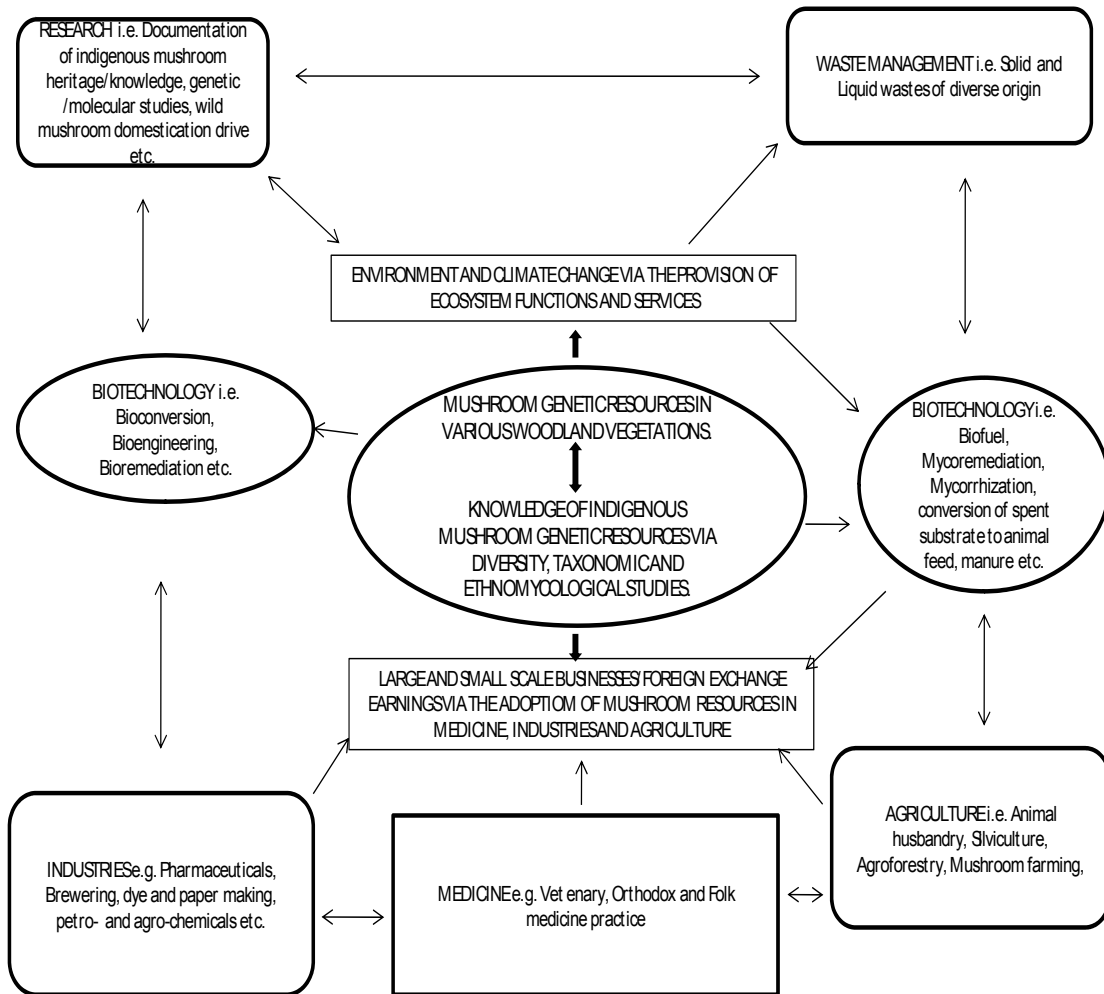


Figure 1: A model showing mushroom genetic resource utilization flow and potentials

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Figure 2: Some exotic, medicinal, edible and economically valuable mushroom resources found in Nigeria (Pictures by Osemwegie, O.O.).

#### Mythological and Medicinal Mushrooms:

Traditionally, mushrooms are used for nutritional, medicinal and mythological benefits in Nigeria (Alabi, 1991; Akpaja et al., 2005; Osemwegie et al., 2006). Labarere and Menini (2000) acknowledged that the uses of mushroom genetic resources are not only of high interest in agronomy, agriculture, human food and animal feed but also for the discovery, production and development of molecules or components with high added value in industries such as chemical and pharmaceutical industries. A model that shows the interaction between maximal utilization of mushroom resources that yields economic benefits and their exploration is attempted in Fig. 1. This emphasized the relative significance of field study and effective documentations as the bedrock for efficient mushroom exploitation. The nutrients and toxicological profile of edible wild mushrooms in Nigeria have been studied (Aletor, 1995; Fasidi and Kadiri, 1995). There is however dearth of information on the anti-oxidant property of edible and medicinal mushrooms indigenous to Nigeria.

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The level of mushroom nutraceuticals on a global scale confirmed that mushrooms are good health food and reports abound in Nigeria on their use for the treatment of malnutrition in infants, diabetes, obesity or hyperlipidemia, sterility, anemia, mumps, fever and protein deficiency (Akpaja et al., 2005; Okhuoya and Akpaja, 2005; Idu et al., 2007). Zadrazil (1984) reported that mushrooms can also be used in improving the digestibility in ruminant animals. Recently, *Ganoderma* species have been successfully tested in poultry farming for the improvement of egg-laying and disease resistant capacity of birds in Nigeria (Ogbe et al., 2008). Although the locals and other folk medicine practitioners demonstrated deep knowledge of the medicinal use of mushrooms (Osemwegie, et al., 2006; Idu et al., 2007), they are however ignorant of the active principle(s) responsible for the remedy observed. This inherited knowledge has been a source of wealth and reference for practitioners. Prolific discoveries of value added products (Table 4) e.g. ergot, cordycepin, cyclosporine, griseoflvin and other antitumour, antiviral, immuno-modulator,

hormonal and antimicrobial products used in medicine and/or pharmacopeias elsewhere in the world are however challenging (Wainwright, 1992; Jonathan and Fasidi, 2005; Gbolagade et al., 2007). Furthermore, the 2009, 2<sup>nd</sup> African Conference on Edible and Medicinal Mushrooms revealed that Beta-glucan based dietary supplements of mushroom origin are effective for the treatment of Buruli ulcer caused by *Mycobacterium ulcerans* in Ghana while *Ganoderma lucidum* (Leyss.) Karst. Tested in separate study for the treatment of *Eimeria tenella* infected broiler chickens in Nigeria (unpublished). Documentations of their uses in the treatment of both human and animal ailments and/or on the production of drugs (molecules) in Nigeria are scanty.

Many of the heresy and mythological records implicated indigenous Nigerian mushrooms in the preparation of different charms (talismans or voodoo) by traditional worshippers (personal communication). They are also symbolically used and given out to adversaries as form of warnings by the Igbo speaking people of Nigeria while the Yorubas used selected mushrooms with psychoactive and hallucinogenic effects for idol worshipping and spiritualism (Oso, 1975; Akpaja et al., 2005; Okhuoya and Akpaja, 2005). The presence of *Schizophyllum* or *Daldinia* species on dead decaying woods posit quality-burning trait or tinder by fire-wood gatherers in Nigeria. A few elders of the Edo/Delta region confirmed that *Ganoderma* species when brewed is good for improving libido and vitality in adults (Osemwegie et al., 2006). The 2<sup>nd</sup> African Conference on Edible and Medicinal Mushrooms in Ghana, March 24-28, 2009, also revealed that *Cordyceps* and *Ganoderma* were being tried for treatment of alcoholism in Asia. A recent study on the ethnomycological uses of macrofungi in Edo State, South-South of Nigeria observed that *Pycnoporus cinnabarinus* (Fr.) Karst was used as hair-dye and lipstick by the maidens of Okomu (Osemwegie and Okhuoya, 2009). The potentials inherent in diverse mushroom-forming fungi around the globe are therefore infinite even amongst Nigerian's mushroom taxa (Fig. 2).

Nigeria by virtue of its vantage tropical location is one of the world's potential hotspots for various forms of biological resources including mushroom (Myers et al., 2000; Akpaja et al., 2003). This position is also derived from the diversity of vegetation i.e. savannah, rainforests, riparian forests and mangroves that characterized Nigeria (Osemwegie et al., 2006; Osemwegie and Okhuoya, 2009). Currently, the exploitation of indigenous Nigerian mycoresources is still overshadowed by the preponderance of green plants. Vigorous researches on these easily-overlooked forest members might evolve an accidental source of drugs that would resolve the world's cancer, AIDS and leukemia problems. The poor knowledge and documentation of mushroom uses in health-care delivery coupled with the lack of up-to-date

inventory on mushroom taxa in Nigeria impairs government efforts at developing complimentary (folk) medicine practices to the level witnessed in China and other Asian countries (Chang and Miles, 1991).

*Agro-Industrial Wastes, Agriculture, Poverty Alleviation And Mycorestoration.*: One of the strongest technical points recently advancing mushroom production in Nigerian besides improving food options is the conversion of ordinarily valueless or toxic wastes of diverse origin to value added products via a permaculture system. Nigeria by virtue of her population size generate several tons of agricultural, industrial, municipal and domestic wastes that overwhelms the nation's waste disposal machinery and are potentially degradable by mushrooms (Okhuoya and Okogbo, 1991; Okhuoya et al., 1998; Osemwegie et al., 2002). These wastes are tried as substrates or solid-waste substrate supplements and/or ingredients for compost in mushroom cultivation (Table 2).

Mushroom-forming fungi are gaining global popularity in both liquid fermentation of industrial effluents and many lignocellulosic wastes such as waste papers, banana and plantain leaves, and/or peelings, sawdust of different tree origin, oil palm fruit fibres, bunches and cakes, (Oei, 1991; Okhuoya and Okogbo, 1991; Okhuoya et al., 1998; Osemwegie et al., 2002;). There are huge potential socio-economic benefits associated with the effective and efficient bioconversion of agro-industrial wastes to valued edible sporocarps (Chang and Miles, 1991). The growth of mushroom production industries and the use of agro-industrial based substrate as the major raw material may provide a partial solution to the nation's waste management problems and pollution challenges, poverty and rising youth unemployment. The potential use of spent substrates in crop farming as soil conditioner and/or mycorrhization practices have also been emphasized by Labarere and Menini (2000) and Wasser (2007). Mycorrhization by spore has been successfully adopted in Congo and South Africa in *Pinus* agroforestry with *Pisolithus tinctorius* (Marx et al., 1993). Documented account in forest and/or agroforest management in Nigeria is dearth despite high incidence of mycorrhiza mushrooms (Fig. 2). To fully tap into the verse mycorrhization potentials of mushrooms, it is significant to improve the nation's knowledge of mycorrhizae diversity and mycorrhizian status of many indigenous Nigerian trees via further studies. Spent substrates derived from a few small-scale mushroom cultivation farms across the country also have been poorly exploited as sources of single-cell protein, animal feeds, organic manure, soil amendments/conditioner and biofuel in Nigeria as observed in some developed nations of the world (Zadrazil, 1984; Labarere and Menini, 2000). This is attributed to inchoate mushroom production,



accessible alternatives such as fertile lands, manure from animal dung and chemical fertilizer, annual national output of used composts and substrates coupled with a lack of technical knowledge on sustainable re-use of spent substrates in the country.

Human activities have been reported to impact negatively on arable lands contaminating them with pesticides, petroleum hydrocarbons, heavy metals and waste engine oil pollutants, and consequently causing arable land shortage and other environmental challenges. A survey of land use practice in Nigeria revealed that bush fallowing is more popular in addressing the problems of contaminated (polluted) and/or low-yield agricultural lands. This practice according to Adedokun and Ataga (2006) allows for the slow process of natural restoration or remediation. Other strategies reportedly used in recovering contaminated farmlands are capital and labour intensive and this include excavation followed by incineration and/or secured land-filling (Adedokun and Ataga, 2006). These methods currently undermine bioremediation posed varying degree of environmental problems to humans. Therefore, the replacement of bush-fallow system with bioremediation in rehabilitating polluted arable land is slowly being embraced as a faster, cheaper and more environment friendly method in Nigeria. Mushrooms through the evolution of specialized feeding habit or saprotrophism along with other plant resources have been tested in this regards. *P. tuberregium* and *P. pulmonarius* were the most widely used mushrooms in bioremediation studies in the country (Anoliefo et al., 2003; Isikhuemhen et al., 2003, Adedokun and Ataga, 2006). There is however no documentation on the use of indigenous Nigerian mushrooms biopulping and delignification process. The observation made by Okolie and Gbuji (2002) that some indigenous mushrooms recorded non-toxic level of cyanide gave credence to the bioaccumulation potential of mushrooms. Ukpebor et al. (2007) has also implicated mushrooms in cassava processing. The *ex situ* application of mushrooms in tackling various oil-spill and heavy metal contamination challenges in Nigeria is uncommon due to failure of field trials of laboratory results (Oghenekaro et al., 2008).

The uses of mushroom-forming fungi in Nigerian agricultural practices is still undefined in the areas of pest and disease control despite reports that *Cordiceps*, *Gibellula*, *Beauveria bassiana*, *Leptinortarsa decenliniata*, *Pseudogibellula* are entomogenous (Thorn and Barron, 1983). Some wood-decaying fungi occurring in Nigeria e.g. *Pleurotus*, *Schizophyllum* and *Hohenbuehelaria* are nematophagous - utilize the nutrient in nematodes to supplement the low level of accessible Nitrogen in their wood substrate (Robert and Hajek, 1993). Few achievements have been recorded using different species of Nigerian mushrooms as

antagonist of other harmful pathogens of both plants and animals (Table 4).

Sources of information on African mushroom germplasm collections, taxonomy of African mushroom taxa and how they have been exploited are scanty (Labarere and Menini, 2000). This lends credence to the fact that systematic documentation of mushroom diversity and conserved data will inspire maximum utilization of mycoresources in Nigeria. Data on mushrooms do not yet compare to those of plant genetic resources around the globe. Although, Nigeria actively contributed to the global plan of action on the state of the world's plant genetic resources, it is still ranked low amongst the few nations of Africa yet to place national *ex situ* collections under the auspices of the F.A.O and develop their own gene bank. The reason for this may be political or attributed to lack of technical knowledge and assistance in the areas of sampling, identifying and preserving mushrooms. Indigenous Nigerian mushrooms are limited to food and folk medicinal uses as well as for income through their sales in village markets. This may have been the reason why conservatively speaking, only roughly less than 20% of the potentials inherent in Nigerian mushroom genetic resources have been tapped. A well established and sustainable national mushroom culture/germplasm bank will improve accessibility to strains that can add value to the growth of industries, economy, medicines, pharmacy, environment and agriculture while encouraging mushroom researches and explorations for human benefits (Fig. 1).

Nigerian mycologists are therefore challenged to collaborate with mycological herbaria and international agencies such as the United Nations and Food and Agricultural Organization for educational, scientific and technical support in the areas of training mushroom taxonomists and improving food security. This is primordial to solving national problems associated with hunger, poverty, economic development, diseases and unemployment using mushroom-forming fungi as veritable tool.

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