

Diseases Affecting Mushrooms in Africa

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ABSTRACT

Diseases affecting Mushrooms in Africa was reviewed in this study. Mushrooms are fleshy saprophytic fungi with noticeable fruiting bodies, achlorophyllous and large enough to be harvested by hand. Edible mushrooms are highly nutritious and can be used as alternatives to meat, milk and eggs. Mushrooms have a history of economic importance in Africa as food and as medicine serving as good health supplements for the treatment of certain diseases of mankind. Mushrooms like other cultivated vegetable crops are subject to attack by pests and pathogens. Mushrooms in Africa are susceptible to a variety of viral, bacterial and fungal diseases that may affect mushroom yield and quality. Intensive cultivation of edible mushroom is often affected by some fungal and bacterial diseases that frequently cause dramatic losses. Pests and disease problems have higher chances of occurring when mushrooms are grown in one location over a long period of time. These infections are also facilitated by the prevalent conditions such as warm temperature, humidity, carbon dioxide levels and presence of pests under which the mushroom cultivation is carried out. There are other major causes of mushroom diseases besides fungi, bacteria, nematodes, viruses or pests. These are abiotic stress namely nutrient deficiencies, toxic chemicals, improper climatic conditions as well as poor ventilation which cause mushroom abnormalities. Some mushroom diseases are very difficult to control. However, careful farm management and extreme hygiene may prevent major attacks. Moreover, shelf life quality is severely affected by diseases that are still asymptomatic at the time of harvest. Strict maintenance of sanitation and hygiene in the farm helps to control mushroom diseases. Some control measures include the use of disinfectants such as chlorine and the application of selected fungicides. However, this involves significant costs and leaves undesired residues in the ecosystem. Most chemicals that are still allowed have failed to adequately control major mushroom diseases as resistance is easily induced. Other control measures such as bio-control and the use of resistant varieties are suggested good alternatives to chemical control. More research is required to detect the best pesticide-free alternatives for controlling the diseases and pests of mushrooms for the preservation of Africa's precious heritage, mushrooms.

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Introduction

Mushroom, called “Elo” in Igbo language of Nigeria, is a fleshy spore bearing fruit body, typically grown above the ground on soil or in its food sources. Mushrooms are fleshy saprophytic fungi with noticeable fruiting body which may be either epigeous or hypogeous and are large enough to be picked or harvested by hand [1,2]. Defined Mushrooms as the fruit of certain fungi analogous to apple on a tree. Mushroom is achlorophyllous, microscopic basidiomycetes species of certain fungi that bear spores embedded into fleshy fruiting bodies and are desirable as food in market places [3,4].

The term “Mushroom” is not a taxonomic division [6]. Most mushroom producing fungi are members of the phylum Basidiomycota or Ascomycota. The two phyla are under the Kingdom Fungi. As a fungus, mushrooms lack chlorophyll and can be found thriving on dead organic matter such as wood, rice straw, plantain leaves and orange leaves [7-9]. Mushrooms exhibit various shapes and sizes ranging from sessile form with typical cap (Pileus), Stalk (stipe), gills (lamellae) on the other side of the cap and a root-like structure [10,11]. The vegetative portion of

the fungus that gives rise to mushroom is a tangle of long cellular thread called Mycelia. The substrates on which a mushroom grows may be bare soil, humus, dung, decayed wood, living trees or other organic materials [7]. The Mycelia grows throughout the substrate and collect nutrients by breaking down the organic materials [12].

Edible mushroom is a mushroom that can potentially be safely eaten including thousands of types of mushrooms that are regularly harvested [13]. Edible mushrooms are recommended by the Food and Agriculture Organization (FAO) as food, contributing to protein nutrition of developing countries dependent largely on cereals [14]. Stated that edible mushrooms are highly nutritious and can be compared with eggs, milk and meat. According to Idio and [15]. Some species of mushrooms such as those belonging to the order Agaricales are edible, while others like *Amanita* species are not safe for consumption.

The history of mushroom could be traced back to the existence of man on planet earth [16]. Reported that thousands of years ago, fructification of higher fungi have been used as a source of food due to their chemical composition which is attractive from their nutritional point of view. These mushrooms are native to the tropics; including Africa, Asia and Australia [8,17]. Reported that from early stages of civilization, desert macrofungi in forms

of mushrooms and truffles have been used as food and medicine. Reported that mushrooms have a history of economic importance in Africa as food and as a medicinal mushroom [18].

Reported that mushroom is a source of some minerals including iron, selenium, potassium and phosphorus. Mushrooms are economically important not only for their splendid tastes but also serve as good health supplement [19,20]. Studies have been carried out on the application of mushrooms as sources of minerals (iron, calcium and phosphorus), vitamins (B,C and D) and treatment of certain diseases of mankind such as cancer, asthma, coughs and diabetes in some parts of Nigeria [21,22,24,6]. reported that the level of mushroom nutraceuticals on a global scale confirms that mushrooms are good health food and information abound in Nigeria on their use for the treatment of malnutrition in infants, diabetes, obesity or hyperlipidemia, sterility, anemia, mumps, fever and protein deficiency, thus improving the treatment of diseases using fungal drugs. [4]. reported that research examining mushrooms has been done predominantly in Nigeria where it is utilized in many tribes as a significant food source as well as remedy for various ailments.

Mushrooms like other cultivated vegetable crops are subject to attack by pests and pathogens [5]. The major constraints to mushroom production as shown by are pest infestation (77.7%) and shortage of water (70.5%). [25,26]. pointed out that intensive cultivation of edible mushrooms is often affected by some fungal and bacterial diseases that frequently cause dramatic production loss. [27,28]. Reported that these infections are facilitated by the prevalent conditions under which the mushroom cultivation is usually carried out, such as warm temperatures, humidity, carbon dioxide (CO₂) levels and presence of pests [29]. Noted that due to these reasons, mushroom growers are frequently challenged by mushroom disease of bacterial and fungal origins.

Reported that growers have equally faced serious challenges caused by various viral infections [30]. Mushroom survival and multiplication are associated to a number of factors which may act individually or have interactive effects among them [31,28,32,14,5]. noted that there are other major causes of mushroom disease besides fungi, bacteria, viruses or pests. These are abiotic stress namely; nutrient deficiencies, toxic chemicals, carbon dioxide levels, improper climatic conditions as well as poor ventilation. They reported that these factors cause mushroom abnormalities. This review work therefore aims at investigating the diseases and pests affecting mushrooms in Africa.

Mushroom Abnormalities

Noted that there are other major causes of mushroom disease besides fungi, bacteria, viruses or pests [32,14,5]. These are abiotic stress namely; nutrient deficiencies, toxic chemicals, carbon dioxide levels, improper climatic conditions as well as poor ventilation. These workers reported that these factors enumerated above usually cause mushroom abnormalities. These abnormalities or disorders include the following;

a. Formation of Scales or “Crocodile Skin” :(Scaliness)

This is a scaly appearance on the cap surface. It can range from very mild with little effect on quality to very severe discolouration with scales. Some strains are more susceptible than others. First flush of mushrooms appear more susceptible than later flushes. [14]. pointed out that the main causes of scaliness are as follows;

- i. The passage of very dry air over the surface of mushrooms
- ii. Strong air movement with low relative humidity
- iii. Short comings in the air supply and distribution system
- iv. Tendency of the strain to form scales
- v. Damage done by pesticides

b. Formation of Stroma and Overlay:

Stroma is a dense mass of mycelium growing on the surface of the casing without fruiting. This often leads to reduced pinhead formation and interferes with watering because the mycelium “seals” the casing so water cannot penetrate. Overlay is continued vegetative growth of mycelium in and over the casing. Stroma is a genetic malfunction in a spawn culture that is sometimes triggered by an environmental factor [32,14]. Major causes of stroma are;

- i. Low quality degenerating mushroom strain
- ii. Mycelia growth in a poorly ventilated casing with a high concentration of carbon dioxide, high temperature and low humidity and a high volume of evaporation.
- iii. Overly long period of mycelia growth in the casing layer
- iv. Petroleum-based fumes or chemicals

c. Rosecombs: Rosecomb is usually referred to as misshapen cap with grills on the cap. This causes distortions, lumps and gross malformations on the mushrooms. Often gills are present on the top, hence the name, rosecomb [32]. The main causes of rosecombs include;

- i. Casing layer contaminated by mineral oils
- ii. Contamination of the substrate with petroleum-based materials such as oils, diesels or distillate fumes.

d. Outgrowths on Mushroom caps “Cock’s Comb”: According to [32], cock’s comb are usually outgrowths on mushroom cap caused by the following;

- i. An overdose of pesticides
- ii. Casing layer contaminated with chemicals
- iii. Effect of exhaust gases, heating appliances, diesel oil, formalin vapours, solvents and paints

e. Poor and Uneven Mycelia Growth in the Casing Layer: [32], enumerated the following causes of this disorder thus;

- i. Overly high or low temperature of the mixture
- ii. Incorrect pH level of the mixture
- iii. Poor mixing of casing soil ingredients
- iv. Overly humid or overly dry casing layer
- v. Non uniform casing soil application (different height)
- vi. The infection of compost by competing fungi and the pressure of pests

Table 1 summarizes some of the mushroom abnormalities or mushroom disorder, description of major mushroom abnormalities, as well as causes of these mushroom abnormalities.

Table 1: Summary of Mushroom Abnormalities or Mushroom Disorders

Mushroom abnormalities	Description	Causes	References
Formation of scales or “Crocodile skin”	This is scaly appearance on the cap surface as the name implies	Strong air movement with low relative humidity	[14].
Rosecomb	Gills present on mushroom cap	Contamination of the substrates with petroleum-based materials such as oils, diesels or distillate fumes	[32].
Outgrowths on mushroom caps or “Cock’s comb”	Outgrowths on mushroom caps	Casing layer contaminated with chemicals	[32].
Long stipes	Growth of a big amount of mushrooms due to excessive pin formation and accumulation of a great amount of CO ₂	<ul style="list-style-type: none"> • Mummy disease • Virus disease 	
Formation of stroma or overlay	Stroma is a dense mass of mycelium growing on the surface of the casing without fruiting. Stroma is a genetic malfunction in a spawn culture that is sometimes triggered by an environmental factor	Mycelial growth in a poorly ventilated casing layer with a high concentration of carbon dioxide, high temperature and low humidity and a high volume of evaporation	[32].
A change in colour of fruit bodies (darkening)	The mushroom fruit body changes in colour and becomes dark	<ul style="list-style-type: none"> • Phenolic vapours • Improper use of pesticides • Bacterial blotch diseases 	[14].

Major Diseases of Mushrooms in Africa

Fungal and bacterial diseases are the major problem in mushroom cultivation [29]. A high percentage of products are lost due to lower productivity, decrease in quality and shortened shelf life. Major diseases of mushroom in Africa include;

Fungal Diseases

a. Dry Bubble: Dry bubble is a fungal disease caused by *Verticillium fungicola*, a devastating pathogen in the mushroom industry, which causes significant losses in the commercial production of mushrooms [29]. Main sources of infection include; debris, dust on floors of growing house, spread, water splashes on healthy mushroom, sciarid and phorid flies over long distances, favourable temperature (28OC), poor ventilation and high humidity. enumerated the symptoms of dry bubble disease as follows;

- Muddy brown often sunken spots on the cap of the mushrooms
- Greyish-white mouldy growth seen on pileus
- Later stage of mushroom becomes dry and leathery
- Initially infected ones are not developed or remain small

b. Green Mould: [33].described any disease caused by green mould on mushroom bags or beds as “Green mould disease”. The causal agents of green mould disease on oyster mushroom are reported as *Trichoderma virens*, *T. viride*, *T. harzianum* and *T. koningii* in Korea. *Trichoderma* species are sexual, soil-inhabiting filamentous fungi with teleomorphs belonging to the genus *Hypocrea* (Ascomycota, Pyrenomycetes, Hypocreales, Hypocreaceae) [34]. Green mould infection is transmitted by substrates for mushroom cultivation. [35]. observed that *Trichoderma* species were present at the initial phase of substrate preparation but later disappeared with pasteurization. Symptoms of Green mould disease according to [33]. include;

- Appearance of green colour when pathogen produces conidiospores from aerial hyphae
- Green mould fungi form denser mycelia and more aerial hyphae
- If stroma appears, the pathogen has already occupied the substrate deeply and to a wide extent.

- Mushroom hyphae stop their growth around the green patch and are gradually covered by green mould.

c. Wet Bubbles: This disease like dry bubble is soil-borne. Infested soil may be primary source of infection. Infection usually occurs at casing. The disease is spread within a house mainly by water splash, on clothing, equipment, flies or mites [5]. The causal agent for dry bubble is *Mycogone perniciosa*. Symptoms of dry bubble disease according to Anon (2004) include the following;

- Malformed mushrooms with swollen stipes
- Reduced or deformed caps
- Undifferentiated tissue becomes necrotic and a wet, soft rot emit bad odour
- Young pin heads infected by *Mycogone perniciosa* grow into shapeless lumps cauliflower-like which have a velvety appearance initially and eventually break down producing small amber droplets of liquid on the surface.
- It can also appear as gray fuzzy growth on gills (a series of radially arranged (from the center) flat surfaces located on the underside of the cap on which spores are formed)
- Mushrooms become brown in colour
- Bubbles may be as large as a grapefruit
- The fungus is spread through airborne dust and contaminated casing

d. Cobweb: Several species of *Cladobotryum*, including *C. dendroides*, *C. mycophilum*, *C. varium*, *C. multiseptatum*, and *C. verticillatum* are known to be the causal agents of “Cobweb disease” in cultivated mushroom, *Agaricus bisporus* and are found in mushroom-growing countries worldwide. However, [36,37]. Studied and reported that some commercially grown *Pleurotus eryngii* showed similar symptoms to the fungal disease caused by *Cladobotryum mycophilum* in *Agaricus bisporus*. Symptoms of cobweb disease according to Anon (2014) include;

- White silky growth over surface of the casing soil
- Older mycelium changes from silky to glandular white
- Later engulfed by cottony ball of mycelium
- Cobweb mould is darker than mycelium, almost grey as compared to white

- Serious problem where all year round cultivation is practiced
- Main source of infection is casing soil
- Cobweb mould is favoured by high humidity

Bacterial Diseases

a. Bacterial Yellowing: Bacterial yellowing is one of the diseases observable during the cultivation of *Pleurotus eryngii* [39]. pointed out that whatever the growing procedure is yellowing can cause the most severe damage. The disease is characterized by a yellow discoloration of the pileus and hydropic, often elongated and coalescing areas of the entire stem. Symptomatic basidiomata then stop growing turn a reddish-brown colour and are affected by rotting. Diseased sporophores exhale an odour which is almost alcohol-like and pleasant at first, but rapidly becomes offensive and nauseating [39].

Pseudomonas agarici and *Pseudomonas reactans* are reported as the most likely causal agents of yellowing in both *Pleurotus eryngii* and *Pleurotus ostreatus* (Jacq.) *P. kumm* [41,39]. reported that the yellow blotch in *P. ostreatus* caused by *P. agarici* formed a clean yellow fluid on the surface of the cluster at first and then deformed with an increase in severity. The major symptoms of bacterial yellowing are yellowing of the pileus.[29]. reported that yellowing of *P. eryngii* can occur in all basidioma development phases, from primordia appearance to commercial maturation.

b. Bacterial Brown Blotch: Bacterial brown blotch is also known as bacterial spot or bacterial pit (Anon, 2014). *Pseudomonas tolaasii* is the causative agent of bacterial blotches in the button mushroom, *Agaricus sp*, in *Flamulina sp*, in oyster mushroom *Pleurotus sp* and in shitake *Lentinus edodes* [42,29]. reported that the bacterial brown blotch disease caused by the bacterium *Pseudomonas tolaasii*, has been one of the most serious bacterial diseases for the oyster mushroom, *Pleurotus ostreatus*. The disease often occurs over a large geographical area. The disease incidence has been different each year. Once the disease occurred on a farm, it becomes very difficult to control before all of the substrate bags were removed from the farm [43]. Observable symptoms of bacterial blotch disease [42,43]. include the following;

- Pale yellow spots on the surface of the pileus which later turns to yellow
- Blotches appear in early button stage
- High humidity and watering conditions are favourable for the disease.
- Discolouration is superficial (not more than 2 to 3mm)
- Underlying tissue may appear to be water soaked and grey
- At favourable moisture conditions, spots enlarge and coalesce, sometimes covering entire cap
- Typical spotting is observed at or near the edge of mushroom caps wherever caps remain wet for a period of 4 to 6 hours or longer after water has been applied
- Casing and air-borne dusts are primary sources. The bacterial pathogen is probably present in most casing material, even after pasteurization.
- Spread is by splash, tools, flies and nematodes.

c. Soft Rot: The gram-negative bacterium *Pantoea spp* has been reported as a causal agent of soft rot disease with symptoms of water-soaked lesions on the stipes and pileus of *Pleurotus eryngii*

[44,45] reported that the genus *Pantoea* includes several species that are generally associated with plants, either as epiphytes or as pathogens. [46]. isolated strains belonging to *Pantoea beijingensis* (growth occurs at 10-37°C) from lesions on the fruiting body of *Pleurotus eryngii* exhibiting symptoms of water-soaked lesions and soft rot in the stipes and pilei. Typical symptoms of soft rot disease include a dark brown water drop in the early stages of infection, followed by the development of water-soaked lesions on the stipes and cap of mushrooms within 8 days after the mushrooms are transferred to the cultivation room. The lesions expand gradually and constitute a viscous, mucus-like fluid, finally leading to a mushy soft rot accompanied by an offensive odour during growth [45,46].

d. Stipe Necrosis: *Ewingella americana*, an opportunistic pathogen has been identified as the causal agent of internal stipe necrosis on symptomatic samples collected from mushroom farms [47,48]. demonstrated the predominance of *Ewingella americana* in biota of retail fresh *Pleurotus ostreatus*. The symptoms of internal stipe necrosis appear as a variable browning reaction in the center of the mushroom stipe [49]. Examined in longitudinal section, the brown tissue extends from the base of the stalk to the cap, but rarely penetrates the cap tissue. Affected mushrooms may be wet in appearance, but frequently at harvest; the brown tissue is dry and has completely collapsed, leaving a hollow center. In all cases, symptoms are visible only at harvest. [53]. pointed out that the occurrence of internal stipe necrosis disease has occasionally been associated with water-logging of the mushroom stalks at an early development stage.

[29]. reported that mycoviruses are widespread in fungi, including plant-pathogenic fungi. In most cases, they have been reported to be cryptic or show few symptoms leading to latent infection in host cells. Mycoviral infection symptoms include retarded mycelia and fruiting body growth, fruiting body development inhibition and malformations of the fruiting body [50]. Concluded that it is possible that many uncharacterized mushroom diseases may be related to mycoviral infection.

a. “La France” Disease: Isolated the oyster mushroom isometric virus (OMIV) [51]. Typical symptoms of viral disease on oyster mushroom are quite similar to “La France” disease which is a well-known viral disease in *Agaricus bisporus*, in which fruiting body formation delay, shortening in stipe, abnormal shape and thin mushroom caps are the major symptoms. [33]. reported that fruiting bodies are not formed at all on some infected mushroom beds and viral-infected hyphae grow very slowly on agar and their density is very low.

b. Die-Back Disease: Reported that mushroom industries often suffer from spawn-related diseases, most notably the die-back disease, which originates from a viral infection [50,52]. isolated the first single-stranded ssRNA mycovirus named Oyster Mushroom Spherical Virus (OMSV), from a cultivated oyster mushroom, *Pleurotus ostreatus*. OMSV is a causative agent of the die-back disease. The symptoms are rather complex and the disease spreads fast. An outbreak of such disease in a commercial farm often leads to a complete loss of yield and it is difficult to control. Table 2 summarizes the major diseases of mushroom in Africa.

Table 2: Summary of Major Diseases of Mushrooms in Africa

Sources	Diseases	Causative agent	References
Fungal	Dry bubble	<i>Verticillium fungicola</i>	[29].
	Green mould	<i>Trichoderma viride</i>	[34].
		<i>T. harzianum</i>	[35].
	Wet bubble	<i>Mycogone pernicioso</i>	[5].
	Cobweb	<i>Cladobotryum mycophilum</i>	[36].
Bacterial	Bacterial yellowing	<i>Pseudomonas reactans</i>	Kim et al (2014)
		<i>Pseudomonas agarici</i>	Bruno et al (2015)
	Bacterial brown blotch	<i>Pseudomonas tolaasii</i>	Han et al (2012)
			Zhang et al (2007)
	Soft rot	<i>Pantoea spp</i>	Kim et al (2007)
			Liu et al (2013)
	Stipe necrosis	<i>Ewingella Americana</i>	Reyes et al (2004)
		Fletcher and Gaze (2008)	
Viral	“La France” disease	Oyster Mushroom Isometric Virus (OMIV)	Ro et al (2006)
	Die-back	Oyster Mushroom Spherical Virus (OMSV)	Kim et al (2008) Yu et al (2003)

Pests of Mushrooms in Africa

The presence of pests such as insects, mites, crustaceans, and other mycetophagous arthropods and synthetic or wood substrate decomposers have been identified by producers as damaging or limiting the proper development of mushrooms. [29]. reported that biological cycles of these pests are not well known. Table 3 summarizes the different pests of mushrooms.

Table 3: Harmful Pests of Mushroom Crops in Africa

Pests	Damage done	Control	References
Nematodes	Knots on the gills	Screen net	[54]
Mites	Feeds on mycelia and fruiting bodies; carry pathogens and nematodes	Smoke extract	[33]
Mushroom flies	Perforates the stipe and pileus, opening galleries in their interior, causing its overall depreciation. Adult flies spread diseases and mites.	Alcohol (80%), pyrethroids and water sticky traps (white or yellow-coated, double-sided)	[27]
Beetles	Lay their eggs inside the mushroom and when hatched feed on nutrients from mushrooms	Pepper mash or bordeaux mixture with adhesive	[27]
Molluscs	Feeds on mushrooms at the beginning of shaping	Quicklime	[33]
Rodents	Feeds on mycelia and fruiting bodies	Calcined gypsum with wheat flour or boric acid-based bait	[28]
Termites	Feeds on fruiting bodies	Gasoline or mothballs with insecticide around the cultivation area	[14]

Basic Practices for Mushroom Disease and Pest Management

A wide range of diseases and pests pose serious problems to mushroom cultivation. Conditions necessary for mushroom cultivation such as high humidity and warm temperature are favoured by many pathogens that cause diseases and pests. Therefore, management of those diseases and pests is a key factor in successful mushroom production [33]. In Mushroom Grower’s Handbook 1, [33]. Enumerated the basic practices for disease and pest management. These include the following;

1. Sanitation and strict hygiene are the most important preventive methods for pests and disease control. Every practice must focus on exclusion and elimination of pathogens or pests
2. Record keeping is very important to identify where the problems arises. Information required includes dates of all phases of production and particularly their parameters such as temperatures, moisture levels, pasteurization times, etc.
3. Identify the particular problem in order to take appropriate actions for better management.
4. Doors should be kept closed and practices that expose substrates to pathogens or pests during spawning should be avoided
5. Install screens on windows and doors to keep mushroom flies from entering mushroom houses.
6. Inspect mushroom bags or beds carefully for early detection of pests and diseases.
7. Keep the floors clean. Do not dump any waste near mushroom houses to avoid attracting mushroom flies.
8. Disinfect or pasteurize spent substrates before removing it from houses after cultivation.
9. Clean and disinfect mushroom houses thoroughly before a new crop.
10. Clean and disinfect equipment frequently.
11. Wear clean clothes and shoes and wash hands before entering mushroom houses.

Control Measures for Diseases of Mushrooms in Africa

Reported that there are a whole range of diseases and pests that can attack mushrooms [55]. According to them, the longer mushrooms are grown in one location, the greater the chance of having pest and disease problems. Some mushroom diseases are very difficult to control. Although careful farm management and extreme hygiene according to [29]. May prevent major attacks. Moreover, shelf life quality is severely affected by diseases that are still asymptomatic at the time of harvest [55]. Therefore maintained that it is very important to strictly maintain sanitation and hygiene in the farm which includes sterilizing growing houses, proper disposal of spent substrate, etc). Hence, they suggested that record keeping is important to identify where problems arise.

Some control measures enumerated by [29]. Include the use of disinfectants such as chlorine (household bleach) and application of selected fungicides which is generally practiced in the cultivation of mushrooms and involves significant costs. However, [56,29]. reported that the use of chemicals in cultivation leaves undesired residues, several of which have been banned from use. Most chemicals that are still allowed have failed to adequately control major mushroom diseases as resistance is easily induced [57]. Other control measures such as bio-control and the use of resistant varieties are suggested good alternatives to chemical control [29].

Fungal Diseases The control measures for these fungal mushroom diseases are;

a. Dry Bubble: the control of *L. fungicola* relies on strict hygiene, regulation of the environment and the routine fungicide spray program [29]. Few chemicals can be used for the control of dry bubble because the host is also sensitive to fungicides. Notably, the development of resistance of *L. fungicola* has been reported against the fungicides that are used to control dry bubble disease [58]. The effective and currently legal chemical control for dry bubble disease is sporgon (active ingredient: prochloraz-manganese). Another management technique that has been recently researched is the use of volatile 1-octen-3-ol on infected hosts of *L. fungicola*. [58]. reported that 1-octen-3-ol inhibits the germination of *L. fungicola* and that enhanced levels can effectively control the

pathogen. Anon (2014) pointed out that basic management practices of disease and pest control such as good sanitation, proper pasteurization of casing material and low temperature during spawn run can control the dry bubble disease. For protective measure, the use of zineb and the application of chlorothalonil at casing or mix into casing material (Anon, 2014).

b. Green Mould: suggested the application of calcium hydroxide on the affected area [59]. Reported that the use of fungicides benomyl, thiabendazole and prochloraz was also reported to be effective [60]. Prochloraz was shown to be the most effective fungicide for the inhibition of mycelial growth in green moulds because the amount of resistant *Trichoderma spp* isolates was the lowest when analyzing this fungicide. thymol, ferulic acid, (+)-menthol and (-)-menthol inhibited green mould growth at concentrations as low as 0.08 mg/ml to 1.25 mg/ml [61].

c. Wet Bubbles: According to Anon (2014), sanitation in growth house is very important in the control of the disease, wet bubble. The worker suggested control measures such as the following listed below;

- clean environment around cultivation area
- incorporating benzimidazoles in the casing
- application of benomyl at the rate of 0.95 g/m², and
- carbendazim and thiabendazole at the rate of 0.62 g/m²

d. Cobweb: Basic management practices of the disease according to Anon (2014) include;

- Identify disease symptoms early not only the web but also cap spotting
- Treat spotty infections with an alcohol drenched paper towel
- Cover infected areas with salt
- Heavily infected second and third breaks should be steamed off to reduce the spore load on the farm
- Control strategies include lowering humidity and/or increasing air circulation
- Increased hygiene of the harvesting and watering department
- Judicious applications of benzimidazole fungicides should be made
- Chlorothalonil should be included in the fungicide application program

Reported that the fungal pathogen, *Cladobotrym spp* is sensitive to metrafenone (0.025 ppm), prochloraz manganese (0.3 ppm), chlorothalonil (0.45 ppm), benomyl and carbendazim (< 1.0 ppm) as well as moderately sensitive to thiophanate-methyl (2.0 to 8.0 ppm) and thiabendazole (4.85 ppm) [29]. In addition, combining the active ingredient with prochloraz manganese and thiophanate-methyl might help to prevent or at least decrease the risk of the pathogen becoming resistant [36,41].

Bacterial Diseases: The following are control measures of major bacterial diseases. Bacterial diseases can be prevented by taking the following precautions according to [27]. Such as environmental controls including low relative humidity, temperature, and carbon dioxide level as well as cleaning cultivation rooms play important roles in diminishing the spread of the disease. [62]. emphasized the importance of keeping mushroom caps dry by regulating temperature, relative humidity and ventilation to prevent bacterial propagation in the cultivation rooms. The following are control measures for these bacterial mushroom diseases.

a. Bacterial Yellowing: Reported that mushroom producers generally try, albeit with disappointing results, to prevent yellowing or halt its development and spread by adding sodium

hypochlorite or chemicals containing iodine to irrigation water [39,29]. reported that much research has been done to figure out an adequate method to prevent or control this disease. Controls such as lowering relative air humidity and watering with low concentration of chlorine solution (calcium chloride and chlorinated compounds) are currently the most commonly utilized chemicals for blotch disease control. Several other disinfectants and antibiotics such as chloramine T and bronopol, essential oils and kasugamycin have also been tried for their ability to control bacterial blotch disease [63]. It is safe to say that acetic acid at 87.4 and 69.9 mM may be considered an interesting antibacterial tool to prevent and/or halt the yellowing of *Pleurotus eryngii* [39].

b. Bacterial Brown Blotch: Bacterial brown blotch disease have been reported to cause huge economic damage due to a rapid spread of the bacterial pathogen in *Pleurotus eryngii* cultivations and effective biological or chemical control measures are scarce [29]. Biological control methods with antagonistic microorganisms and/or specific phages have also been investigated [64]. Reported that a gram-positive bacterium, strain 9045, detoxifies tolaasins produced by *Pseudomonas tolaasii* and significantly suppresses the onset of the disease in *Pleurotus ostreatus*. Strain ACCC50618 was resistant to brown blotch disease [65]. However, it has rarely been cultivated by growers because the fruiting bodies are very fragile and can easily be broken during harvest and transported. Anon (2014) suggested that good sanitation as well as lowering humidity and watering with a 150 ppm chlorine solution (i.e. calcium hypochlorite products are used since sodium hypochlorite products may burn caps).

c. Soft Rot: Pointed out that compounds containing active chlorine are at present the most commonly utilized chemicals for bacterial disease control [46]. Reported that watering with concentrations at 175 ppm active chlorine were effective for the reduction of soft rot disease of *Pleurotus eryngii* without affecting mushroom yield.

Viral Diseases: Suggested the following as control measures for viral diseases of mushroom. They are as follows;

- Spray the wood with 2% sodium pentachlorophenate and 1.0% sodium carbonate
- Disinfect doors, little holes in the floor, shutters, racks, floors and walls with formalin (2%). Also clean the compost yard and surroundings with formaldehyde.
- Immediately after spawning, spray malathion at 0.05% and cover the compost with paper. Also spray 1% formalin weekly on the newspaper sheets during spawn run.
- Quickly remove cuttings/ litter and destroy
- The entire farm and its surroundings should be maintained very clean. Formalin (2%) should be sprayed in the working corridor. Machines, refrigerator and other utilities should be disinfected with formalin (2%) solution. In summary, common chemicals used to control diseases of mushroom in Africa is given in table 4 below.

Table 4: Common Chemicals Used to Control Diseases of Mushrooms in Africa

Chemical compound	Pathogen affected	Dosage
Benomyl and Carbendazim	Dactylium, Mycogone, Trichoderma, Verticillium	Mix 240 g/100m ² with casing or in water at 240 g/200 l/100m ²
Chlorothalonil	Mycogone, Verticillium	200 ml/200 l/100m ² . First spray one week after casing and second spray after two weeks
Prochloroz manganese	Dactylium, Mycogone, Verticillium	300 g/100m ² for single spray or 113 g/100l/100m ² for double spray
Thiabendazole	Dactylium, Mycogone, Verticillium	Mix 240 g/100m ² with casing or in water at 240 g/200l/100m ²
Zineb	Dactylium, Mycogone, Verticillium	350 g/100m ² , dust every week after casing or 1 kg/1000 litres at 5l/10m ² after casing and between flushed
Sodium hypochlorite and chlorine solution (Calcium chloride and chlorinated compounds)	<i>Pleurotus eryngii</i>	Dilute with water with concentrations at 175 ppm active chlorine
Acetic acid	<i>Pleurotus eryngii</i>	87.4 mM and 69.9 mM
Sodium pentachlorophenate and sodium carbonate	<i>Agaricus bisporus</i>	Spraying 2% sodium pentachloropenate and 1.0% sodium carbonate
Formalin	<i>Pleurotus ostreatus</i>	Spraying of 2% formalin solution in the entire farm house

Source: Anon (2014); Bellettini et al (2017)

Control Measures for Mushroom Pests

According to Anon (2020a), there are various measures available to control pests of mushrooms in Africa and these include; physical exclusion, biological control and chemical insecticides. Anon (2020a) reported that pests from the family Sciaridae and Phoridae cause the most havoc in mushroom farms. Sciaridae [66]. are a family of flies, commonly known as dark-winged fungus gnats, which are commonly found in moist environments. They are known to be a pest of mushroom farms and are commonly found in household plant pots as well [67]. Pointed out that Phoridae are a family of small, hump-backed flies resembling fruit flies. Phoridae flies can often be identified by their escape habit of running rapidly across a surface rather than taking to the wing. This behaviour is a source of one of their alternate names, scuttle fly

a. Physical Exclusion: Physical exclusion as the name implies involves the removal of all objects or materials that breeds pests in the mushroom farms. Anon (2020a) reported that in common with most insect pests' problems, preventative measures are an essential element of control.

- Adult flies must be prevented access to phase II compost from cool-down and throughout the spawn-run period.
- Screening on ventilation ducts (16 mesh/cm) and efficient sealing on personnel and loading doors are essential.
- Personnel access to production houses, particularly during spawn-run should be restricted to essential crop management practices.
- In addition, sticky traps should be installed and monitored frequently for the occurrence of adult flies, particularly during spawn-run
- Illumination of sticky traps with a fluorescent light source will increase effectiveness of traps

b. Chemical Insecticides: For each crop protection products, the manufacturer's instructions regarding crop, environmental and personal protective safety should be closely adhered to when handling chemical insecticides (or pesticides) Anon (2020a).

- Mushroom production houses may be sprayed or fumigated with aerosol formulations containing the insecticide active ingredient, pyrethrin or a formulation of pyrethrin and resmethrin. Application to be made with "cold fogging" equipment.
- A product containing 10 g/l pyrethrins should be applied as a spray to run off at a maximum concentration of 700 ml product per 100 litres water.
- Fogging with this product should be at a maximum concentration of 1 litre product per 100 litres water.
- Insecticide treatments which target adults only will not control populations effectively
- Insecticide treatments must also be directed at immature stages in the compost and casing to achieve optimum control
- A minimum interval of 7 days must be observed between applications
- Chemical insecticides containing the active ingredient, diflubenzuron (100 g/100m² in 250 litres of water) may be applied immediately after casing.

c. Biological Control: Biological controls are important control measure that involves the use of biological agents in the control of pests and diseases when other methods of control fail. Anon (2020a) reported that there is no commercial biological control agent currently available for phoridae. On the other hand, for sciaridae, the biological control agent *Steinernema feltiae* provides an alternative to chemical control which may also be applied immediately following casing.

- This insect pathogenic nematode which parasitizes larvae is available in pack sizes of 150 and 300 million nematodes and the rate of application is 3 million nematodes /m².
- The nematodes are formulated in a powdered inert vermiculate carrier and must be refrigerated (5-10°C) during storage.
- Application equipment must be clean and free from pesticide residues and fine filters should be removed from the sprayer.
- These biological agents can be integrated with compatible chemicals but they must not be tank mixed.

Conclusion

Mushrooms in Africa have been exploited for their medicinal benefits, nutritional benefits (food), economical, environmental as well as ecological benefits. Mushrooms in Africa produce wide

variety of interesting bioactive compounds of high medicinal value and have been used in the treatment of different diseases. Yet this source of healthy alternative to food, medicine and unemployment is fraught with diseases and pests.

There is a wide gap in the area of research, development and awareness creation about the benefits of mushrooms. Mushrooms indigenous to Africa have enormous potentials as sources of bioactive agents for biopharmaceutical exploitation. Hence, it is imperative to carry out research in these areas; Ecological survey, Molecular identification and assessment of the medicinal potentials of these mushrooms. This will ensure the full and sustainable exploitation of these mushrooms.

Sustainable exploitation of these mushrooms indigenous to Africa will lead to the emergence of myconutraceutical industries which will help in tackling the problem of unemployment and consequently reduce adverse poverty and curb food insecurity. More research will also detect the best pesticide-free alternatives for controlling the diseases and pests of mushrooms for the preservation of Africa's precious heritage, mushrooms. Data on mushrooms in Africa do not yet compare to those of plant genetic resources around the globe. Few nations of Africa are yet to place national ex situ collections under the auspices of the F.A.O and develop their own gene bank.

Recommendations

1. More research and enlightenment of the populace is required.
2. Development of pesticide-free alternatives for the control of diseases and pests of mushrooms for the preservation of Africa's precious heritage, mushrooms.
3. Establishment of mushroom germplasm collections/ Gene bank
4. More healthy exploitation of African mushrooms
5. Explicit Identification, Characterization and Taxonomy of African mushroom taxa
6. More collaborations with other African mycologists to chart a way forward

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