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Edible and Non-Edible Wild Mushrooms: Nutrition, Toxicity and Strategies for Recognition

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Abstract

Mushrooms can be found extensively in a variety of natural environments and visual identification of mushroom species is well established. Some mushrooms are known because of their nutritional and therapeutical properties. Some species are known all over the world because of their toxicity that causes fatal accidents every year mainly due to misidentification. Some of the edible mushrooms are *Ganoderma* spp, *Cantharellus* spp, *Agaricus* spp, *Pleurotus* spp, *Russula* spp, *Auricularia* spp and *Termitomyces* spp; but the ornamentals are the beautifully ringed *Microporous* spp. *Amanita* spp, *Lepiota cristata*, *Lepiota brunneoincarnata* and *Inocybe asterospora*, *Coprinus* spp are among the most important species responsible for mushroom poisoning. Morphological and chemical analyses for mushrooms are occasionally required in forensic science practice. In this work, the characteristics of the representative toxic mushrooms and some chemical methods for their toxins are presented. Mushrooms are identified traditionally by their appearance, taste, colour, odour, presence of scales etc. However, further studies using modern methods of characterization involving molecular tools are required to improve on such strategies.

Keywords

Mushroom; Poisoning; Edible; Toxins; Molecular tools

Introduction

The word mushroom has been used in a variety of ways at different times and in different countries. Generally, mushroom refers to all larger fungi, those fungi that have stalks and caps, or all large fleshy fungi. Though a restricted use of mushroom means simply larger fungi that are edible this may have medicinal value. The term mushroom is also used extremely to mean only the edible species of *Agaricus* [1]. Broadly mushrooms are macro fungi with a distinctive fruiting body which may be found above the ground or underground. They grow large enough and can easily be recognized with the naked eye and can be picked by hand [2]. By that understanding it means that mushrooms must not necessarily be Basidiomycetes, nor aerial, nor fleshy, nor edible. Mushrooms can be Ascomycetes, can grow underground, have a non-fleshy texture, and need not be edible. This definition may be generally applicable in the current dispensation of mushroom development where different species of mushrooms exist in farms worldwide and with the advent of new technologies involving mushroom production.

Mushrooms and fungi in general are non-green organisms lacking chlorophyll. They cannot manufacture their own food from simple inorganic materials, such as water, carbon dioxide, and nitrates, using energy from the sun, as is the case with the green plants. They derive their food from complex organic materials found in dead or living tissues of plants and animals. Those obtaining their nutrients from dead organic material, e.g., agricultural crop residues, wood of dead trees, animal dung, etc., are referred to as saprophytic fungi. Those deriving their food substances from living plants and animals and causing harm to the hosts are called parasitic fungi. Such fungi are often of great concern to farmers because they cause enormous crop damage and even lead to severe food shortages. But there are also some fungi whose members live in a close physiological association with their host plants and animals (e.g., those living inside nests of termites or mushrooms living in association with roots of some grasses or trees such as pines) and in a special type of partnership, whereby each partner enjoys some vital benefits from the other. These are referred to as mutualistic symbiotic fungi.

Picking mushrooms from the wild for food is an age long practice in Africa. Recognition of edible from non edible mushrooms is simply an art that is being handed from generation to generation. Occasionally, there are miscalculations in this art due to close resemblance of mushroom species and non-edible mushrooms are picked and consumed by families resulting in high level consequences. Mushroom poisoning (also known as mycetism or mycetismus) which is the harmful effects from ingestion of toxic substances present in a mushroom has occurred in many rural population in Africa where health care facilities are very poor or completely absent. Poisonous mushrooms contain a variety of different toxins that can differ markedly in toxicity. The toxins whose potency is influenced by many extrinsic and intrinsic factors present around the mushroom are secondary metabolites produced in specific biochemical pathways in the fungal cells. Mushroom poisoning is usually the result of ingestion of wild mushrooms after misidentification of a toxic mushroom as an edible species. The most common reason for this misidentification is close resemblance in terms of color and general morphology of the toxic mushroom species with edible species [3]. Unfortunately, not many records of mushroom poisoning and epidemiological studies have been carried out in these rural settings where mushroom poisoning is prevalent.

The symptoms of mushroom poisoning can vary from slight gastro-intestinal discomfort, vomiting to death. It may also vary from gastric upset to life-threatening organ failure resulting in death. Incubation period may range from a day to several weeks after which serious symptoms will occur and before this time the toxins must have attacked the kidney or liver [4].

Edible mushrooms are treated as a garnish or delicacy which can be taken regularly as part of the human diet, healthy food or as functional foods. Mushrooms can be designed to supplement the human diet not as regular food, but for the enhancement of health and fitness which can be classified into the category of dietary supplements/mushroom nutriceuticals [5]. Mushrooms form

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a major part of the ingredients of most dietary supplements which are available in the market today for their presumed health-enhancing benefits.

The major problem arising from eating mushrooms is the inability of mushroom gatherers or mushroom scientists to identify the poisonous mushrooms which contain toxins and can be very detrimental to human health. It has been reported in research study that poisonous mushrooms have killed many life in different parts of the world including Nigeria due to the misidentification of poisonous mushrooms as edible mushrooms [6]. Therefore, the main objective of this study is to describe the nutrition, toxicity and strategies for recognition of wild edible and non edible mushrooms using the physical (morphology), traditional (non-scientific) and chemical (scientific) approaches of identification.

Classification of Mushrooms

Classification of mushroom was made according to the standard procedure in taxonomic identification. Mushrooms were generally classified under Phylum Basidiomycota, Division Eumycota, Subdivision Basidiomycotina, and Class Hymenomycetes. Mushrooms under this class were separated into different orders: Order Agaricales, Order Polyporales, Order Sclerodermatales, Order Aphyllophorales, Order Lycoperdales, Order Auriculariales and Order Tremellales. Mushrooms or toadstools are noted widely in edibility. A relatively few species are delicious, many are edible but tough or of an unremarkable flavor, some are inedible and produce varying degrees of illnesses, some commonly known toadstool are violently deadly poisonous (Table 1) [7].

Even expert mushroom gatherers can have trouble in distinguishing between edible and poisonous species closely resembling themselves. Classification and identification of the edible and non-edible mushrooms are presented in Table 2 and Figure 1 for sample pictures of actual specimens.

Chemical Composition of Mushrooms

The chemical composition of edible mushrooms determines their nutritional value and sensory properties. It differs according to species but also depends on the substrates, atmospheric conditions, age and part of the fructification [8].

Carbohydrate

The carbohydrate content of mushrooms represents the bulk of fruiting bodies accounting for 50 to 65% on dry weight basis. Free sugars amounts to about 11%. Nutritional analysis of two edible wild mushrooms (*S. commune* and *L. edodes*) from northeast India have been studied by [9] and reported that 64.4% carbohydrate content present in *L. edodes* and 68% in *S. commune* (16%). Approximately 34.75% and 38.9% of carbohydrate is present in mycelia and fruit body of *V. bombycina* while the nutritive content of five mushroom species are 49.20, 28.38, 32.08, 34.88, 34.36% carbohydrate content in *C. indica, A. bisporus, P. florida, R. delica,* and *L. decastes*, respectively. The carbohydrate composition of *L. tuberregium* in both wild and cultivated mushroom types were found to be 55.8% and 58.1% respectively [10]. The total carbohydrate content varies from 26-82% on dry weight basis in different mushrooms. In a study by [11], the nutritional values of wild mushrooms were found to be a good source of carbohydrates which ranged from 33.23% in *A. auricula* to 50.2% in *L. tuber- regium*. Proximate composition of four wild mushrooms have been revealed by [10] and found highest carbohydrate (48%) in *M. rhodocus* in comparison to other studied mushrooms. The carbohydrate content of 15 selected mushrooms from Nagaland, India was reported to be between 32.43% in *S. commune to* 52.07 and *Boletus aestivalis* [12]. Recently total carbohydrate contents of two wild mushrooms was studied [13] and highest was found in *L. sajor-caju* (68.24%) and lowest in *L. torulosus* (64.95%).

Fat

The fat content in different species of mushrooms ranges from 1.1 to 8.3% on a dry weight basis, with an average content of 4.0%. In general, the crude fat of mushrooms has representatives of all classes of lipid compounds including free fatty acids, monoglycerides, diglycerides, triglycerides, sterols, sterol esters, and phospholipids. Commonly, cultivated mushrooms were reported to have a higher percentage of saponifiable lipids than non-saponifiable lipid [14]. The values for saponifiable lipid range from 78.1% in *Auricularia auricula* to 58.8% in *Volvariella volvacea*. The low percentage of saponifiable lipid found in *V. volvacea* is mainly due to thepresence of unusually high contents of provitamin D_2 and ergosterol [15].

Vitamins

Mushrooms are an important source of vitamins. The vitamins of group B are abundant [16] particularly thiamine, riboflavin, pyridoxine, pantotene acid, nicotinic acid, nicotinamid, folic acid and cobalamin, as well as other vitamins, such as ergosterol, biotin, phytochinon and tocopherols [16]. The opinion is that, with respect to thiamine content, mushrooms are a bridge between yeast and other food products of vegetal origin [17]. A comparison of the most popular species of edible mushrooms shows that *Boletus edulis* is the species with the greatest content of vitamins of group B, while *Lentinula edodes* contains more folacine, vitamin B_1 and B_3 but less vitamin B_{12} than *Agaricus bisporus* and *Lentinula edodes*. It is also shows that the greatest content of vitamin D can be found in *Lentinula edodes* and *Boletus edulis*. A considerable amount of vitamin, which protects the skin against pellagra, is noted in mushrooms. In 100 g fresh matter of *Agaricus bisporus* about 5 mg of this vitamin can be found, a level not observed in any other food product [18].

Moisture Content

In addition, it is also known that the moisture content of mushrooms depends on their harvesting time, maturation period and environmental conditions such as humidity and temperature in growing period, and storage conditions. The moisture content of all studied mushroom species ranged from 70.00% to 93.31% [18].

Protein

The major compounds of mushrooms are proteins and carbohydrates. It is reported that the protein contents of mushrooms are affected by a number of factors, namely the type of mushrooms, the stage of development, the part sampled, level of nitrogen available and the location. Total protein content, varying between 21-50%, can be accepted high when compared with meat, milk, egg, and fish. It can be understood from the data that the studied mushrooms are good protein sources.

Growth of Mushroom

There are 22,000 named species – mushrooms, toadstools, puffballs and shelf fungi in the phylum Basidiomycota which contains

Table 1: Classification and identification of the edible and non-edible mushrooms.

Kingdom: Fungi	
Phylum	Basidiomycota
Division	Eumycota
Class	Hemenomycetes (open gills)
	Gasteromycetes (closed basidiocarp untilmaturity/ puffballs)
Class	Homobasidiomycetes (for both)
Order	Agaricales(arrange gills)
	Polyporales (network gills)
	Sclerodermatales Aphyllophorales
	Lycoperdales
	Auriculariales
	Tremellales
Family	Agaricaceae
	Chanterellaceae
	Lepiotaceae
Genus	Agaricus
	Amanita
	Ganoderma
	Polyporus
	Chanterella
Species	Campestris
	Cibarius
	Cepaestipes

the most familiar of the fungi. Many among these species are used as food, but others are deadly poisonous [19]. Species cultivated as crops include *Agaricus compestris* which is grown in many countries. Although used as foods, many basidiomycetes such as the rusts and snuts, are responsible for important plant diseases [20].

The basidiomycetes life cycle starts with the production of hypha from a germinating spore. These hypha is non septate at first like the zygomycetes. The basidia occur in a dense layer on the underside of the cap of the mushroom where the surface is folded like an accordion. It has been estimated that a mushroom with an 8 centimeter cap produces as many as 40 million spores per hour [21] (Figure 1).

Edible Mushrooms

Edible mushrooms are the fungi which bear fruiting structures that are large enough to be seen with the naked eye. They may be hypogeous or epigeous and can be picked by hand. What underscores edibility of mushrooms is the absence of poisonous effects on humans and desirable taste and aroma [22].

The nutritional composition of edible mushrooms is high and that is why they are consumed for their nutritional value and supposed medicinal value. Medicinal mushrooms are consumed by those practicing folk medicine for their neutriceutical composition. The hallucinogenic mushrooms like psilocybin mushrooms are consumed for recreational or religious purposes and they can produce severe nausea and disorientation – a reason why they are not commonly considered edible mushrooms [23]

Poisonous Mushrooms

Since there is no known test by which to tell if a mushroom is edible or not, a mushroom should never be eaten unless it has been accurately identified and the edibility of the species is known. Poisonous mushrooms represent less than 1% of the world's known mushrooms hence constitute the dangerous and sometimes fatal species. For this reason, mushrooms must be identified by a competent mycological authority before consumption. Therefore, one must be absolutely sure whether a given mushroom is edible or otherwise before consumption.

The toxins contained in various species are very different in chemical composition, thus the effects of poisoning differ considerably according to the species involved. In any case, suspected mushroom poisoning should never be regarded lightly and medical assistance should be sought at once. The following summary of mushroom poisoning is taken from the account [24].

Amanita-type poisoning

Unquestionably, the *Amanita phalloides* group causes the most dangerous type of mushroom poisoning. The toxins involved belong to the phallotoxin and amatoxin complexes. The phallotoxin phalloidin binds specifically to actin. The phallotoxins are not active following ingestion, but they are potent when injected intravenously and have proved useful in experimental studies. In such studies phalloidin, binding to actin, is coupled with fluorescent groups. By this means actin can be localized in the cells. It is the amatoxin such as amatine that is involved in amanita poisoning. Amatine is a specific inhibitor of RNA polymerase present in all eukaryotes. This blocking of the enzymes associated with the replication of RNA inhibits the formation of new cells. These toxins tend to accumulate in the liver and damage that organ severely. The RNA polymerase of the fungus is not affected. This group has caused the majority of recorded deaths from mushroom poisoning, especially in Europe. Generally the symptoms of this type of poisoning are said to be severe abdominal pains, nausea, violent vomiting, diarrhea, cold sweats, and excessive thirst. These may last for 48 hours, with dehydration, cramps, and anuria [24].

Muscarine-type poisoning

Two toxins, muscarine and ibotenic acid, are involved. They occur in *Amanita muscaria*, *A. pantherina*, and also in a number of *Inocybe* and *Clitocybe* species. Muscarine is known to be responsible for "pupil contraction, blurred vision, lachrymation, salivation, perspiration, reduced heart rate, lowering of blood pressure, and asthmatic-like breathing." [25]. Ibotenic acid is responsible for the insecticidal properties of *A. muscaria*, the fly agaric. Both muscarine and ibotenic acids are intoxicants, and there is a long history of different cultures using these compounds from *A. muscaria* for this purpose and in religious rites. The symptoms usually appear soon after eating the mush- rooms, with vomiting, diarrhea, and salivation. The most characteristic symptoms are nervous excitement, difficulties in breathing, shivering, and a tendency to collapse [25].

Psychotropic or hallucinogenic poisoning

Several different toxins are involved, including psilocin and psilocybin, which are found in species of *Psilocybe, Conocybe,* and *Stropharia*. These compounds are similar in their reaction to *d*-lysergic acid diethylamide. They act on the central nervous system, producing distortions in vision and of tactile sensations as well as mixed emotional feelings of happiness or depression. Other symptoms are varied, including vomiting, increased rate of heartbeat, and hallucinations, which may last for various lengths of time [25].

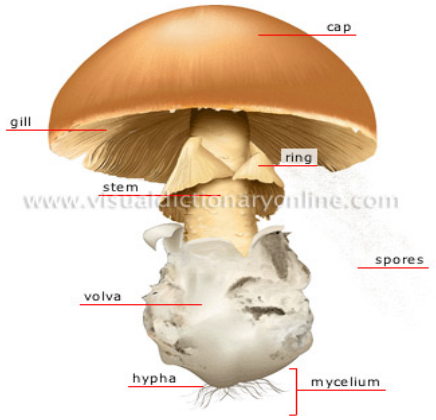

Figure 1: Structure of mushroom.

Coprinus poisoning

Several *Coprinus* species, such as *C. micaceus* and *C. atramentarius*, when consumed with an alcoholic drink, produce unpleasant but not dangerous symptoms. The symptoms include reddening of the face, increased rate of heartbeat, and, in some cases, vomiting and diarrhea. The mode of action of the chemical in *C. atramentarius* mushrooms is similar to Antabuse, which is a drug used to induce nausea and vomiting in individuals who are trying to overcome an addiction to alcohol.

Poisoning from external sources

The poisoning is not caused by mushrooms themselves but by toxic substances that have accumulated in the mushrooms. The principal causes are (1) heavy metals due to polluting environmental conditions where the mushrooms are harvested that are far in excess of permissible levels, and (2) radioactive contaminants due to the pollution by contaminating radioactive materials in mushroom-hunting areas and subsequent consumption of the collected mushrooms.

Toxicity of Mushroom

Toadstool is a name commonly given to poisonous mushrooms. Mushroom poisoning is caused by the consumption of raw or cooked fruiting bodies (mushrooms, toadstools) of a number of species of higher fungi. This poisoning occurs when individuals who are not experts in mushroom identification prepare any type of mushroom for consumption. Mushrooms are generally not easily recognizable between poisonous and non poisonous species. The toxins involved in mushroom poisoning are metabolites produced naturally by the fungi themselves which differ from one species to the other. Individual specimen of a toxic species is considered equally poisonous though the potency of their poisons varies according to species and location of growth. Unfortunately, toxicity of poisonous mushrooms cannot be made nontoxic by any form of processing hence the consumption of the toxic species must be avoided. Mushroom poisonings are generally severe after the incubation period and manifested by a variety of symptoms and prognoses, depending on the amount and species consumed. There is paucity of information on the chemistry of many of the wild mushroom toxins and this makes positive identification of the mushrooms based on physiological effects often difficult. Four categories of mushroom toxins which are recognized are (1) protoplasmic poisons which are poison that result in generalized destruction of cells, followed by organ failure. (2) Neurotoxins which are compounds that cause neurological symptoms such as profuse sweating, coma, convulsions, hallucinations, excitement, depression, spastic colon. (3) Gastrointestinal irritants - compounds that produce rapid, transient nausea, vomiting, abdominal cramping and diarrhea. (4) Disulfiram-like toxins - Mushrooms in this last category are generally non toxic and produce no symptoms unless alcohol is consumed within 72 hours after eating them, in which case a short-lived acute toxic syndrome is produced [26].

Cases of Toxicity of Mushrooms

Mushroom poisoning is a major health challenge in most rural areas of the world with an estimate of over 5000 species of mushrooms worldwide. The continuous search for wild mushrooms is popular in Europe, the United States, and Far East [27] and in Africa. Substantial morphologic variations can occur in the same mushroom species depending on the season, geographic location and maturity of the fungus. Most ingested mushrooms are either nontoxic or only gastrointestinal irritants, resulting in mild to moderate toxic effects [28]. The pathogenicity of mushrooms depends on cyclopeptide toxins and reports indicate that amatoxins account for 90% of fatal mushroom poisonings and have their most significant impact on the liver while mushroom poisonings occur every year between June and December [29]. A study performed in Japan reported that mushroom poisoning happened most frequently in September and October [30]. These reports are dependent on the geographic locations of the mushroom which vary from place to place. Another study performed in Turkey reported that mushroom poisoning usually happened in October and November [31]. A two-year survey conducted by the Food and Drug Administration showed that 21% of cultivated mushrooms were contaminated with toxic look–alike species [32]. Addison [33] reported that in summer of 2013, a case of mushroom poisoning attributed to amatoxin was reported at the North American Mycological Association (NAMA). The patient who presented the case to the Emergency Department of a local hospital in Upper Penisula of Michigan stated that he had eaten poisonous mushrooms. Approximately 12 hours after ingestion, the patient had severe crampimg, abdominal pain with vomiting and profuse watery diarrhea. Northern California reported the sickness in the Centres for Disease Control and Prevention's Morbidity and Mortality Weekly report wild 'death cap' mushrooms poisoned 14 people in Northern California. The 'death cap' mushrooms, *Amanita phalloides*. The toxin is highly volatile when absorbed in the gastrointestinal tract. A report by Live Science [34] indicated that mushroom poisoning caused woman's liver to fail in Canada. The toxicity level depends on the amount ingested and the way in which the mushroom was prepared prior to ingestion. NAMA maintains a case registry where instances of mushroom poisoning are reported. They indicate that distinctive types of mushroom poisoning exist and 10 distinctive patterns of reactions to mycotoxins have been observed in North America. Similar records in the developing countries where foraging for wild mushrooms is high will be helpful as the absence of records does not mean the absence of mushroom poisoning.

Most mushroom toxicity often show a false phase of recovery during which time patients are often discharged from the emergency unit only to return days later to the hospital with more severe problems. Mushroom poisoning patients are to be placed on observation for few days after they show signs of recovery. Amanita species cause increases of AST (Aspartate aminotransferase) and ALT (Alanine

aminotransferase) levels in the serum [35]. The most common toxic symptoms are nausea, vomiting, fatigue, abdominal pain, dizziness, diarrhea, headache and loss of consciousness, have also been reported in the literature [36]. Patients who have jaundice after an acute gastrointestinal episode are suspected to be poisoned with amatoxins. Symptoms of mushroom poisonings with amatoxins begin six to twenty-four hours after the initial ingestion of the mushroom [37].

Mushroom poisoning is a public health problem. People and health care providers must be educated about this poison. The species of mushrooms are numerous, and there are various clinical presentations depending on the ingested species. Children are a high-risk group for wild and uncooked mushroom poisonings. Seven of the world's most poisonous mushrooms are: death cap (*Amanita phalloides*), Conocy bettilaris, web caps (*Cortinarius* species), Autumn skullcap (*Calerina marginata*), destroyin angels (*Amanita* species), Podostron a cornu-damae and deadly dapperliry (*Lepiota brunneoincarnata*).

Scientific Recognition of Mushrooms

Mushrooms from species *Amanita phalloides, Lepiota cristata, L. brunneoincarnata* and *Inocybe asterospora* can be identified mistakenly as edible by the collector. In cases of suspected mushroom poisoning species identification based on morphologic characters is often difficult; the morphology of the mushrooms, particularly of the spores, may be distorted by handling and cooking, and a mycologist might be unable to identify the species. Examination of fungal spores in the gastric contents also may be inconclusive. If poisoning by *A. phalloides* type of mushroom is suspected, gastric contents, mushroom samples and residuals of food if available must be assayed to verify the presence of mushrooms or spores. The development of methods for the identification of poisonous mushrooms thus is important [39].

A molecular method for detection so far has been published only for *A. phalloides* [40]. This method was based on a conventional PCR. It must be emphasized that the detection of a specific fungus requires a few hours with conventional PCR, while real time PCR requires only 1 h or less depending on the apparatus.

Furthermore, as demonstrated by Maeta et al. [39], fungal DNA is detectable in various cooked preparations. The real time PCR amplification of the samples of the four species of mushrooms treated with gastric juice always had higher Ct values than untreated ones. In any case the protocols also exhibited high specificity and sensitivity on the samples treated with gastric juice. The fact that the Ct values from these samples were not too divergent from the ones generated from dried specimens suggests that treatment with gastric juice lead only to a moderate degradation of the mushroom DNA.

Then, the real time PCR protocol also exhibits a number of features that make it a useful diagnostic tool. It is specific, sensitive, quick, and relatively cheap and can function with samples that are difficult to identify morphologically [41]

The most common consequence of mushroom poisoning is simply gastrointestinal upset. Most "poisonous" mushrooms contain gastrointestinal irritants that cause vomiting and diahorrea (Table 2).

α-Amanitin (Figure 2) is a cyclic peptide of eight amino acids and it is about the most deadly of all the amatoxins which is found in several species of the *Amanita* genus of mushrooms. The death caps (Amanita phalloides) as well as the destroying angel are examples which are principally *A. virosa* and *A. bisporigera*. It is also found in the mushrooms *Galerina marginata* and *Conocybe filaris* [41].

Orellanine or **orellanin** (Figure 3) is a mycotoxin found in a group of mushrooms known as the Orellani of the Cortinriaceae family [42]. Structurally, it is a pyridine N-oxide.

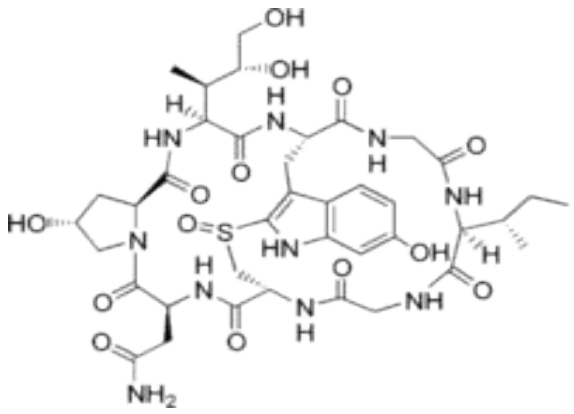

Figure 2: Chemical structure of alpha-amanitin.

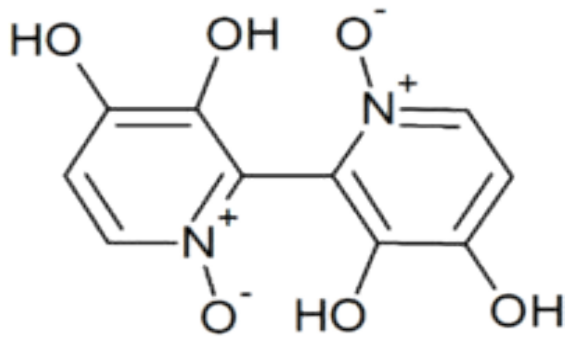

Figure 3: Chemical structure of orellanine [42]

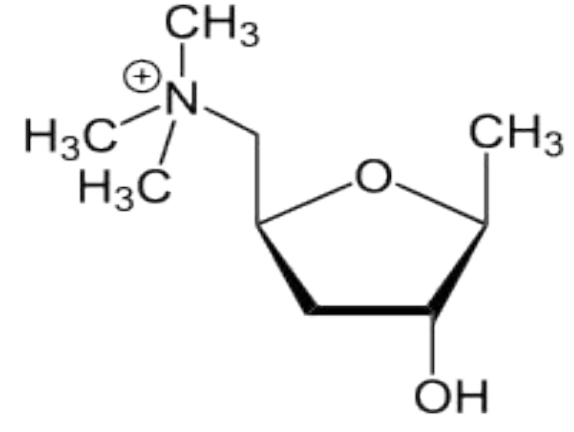

Figure 4: Chemical structure of muscarine [44].

Orellanine can be detected after a relatively long period following poisoning by performing a simple thin layer chromatography technique using small quantities of renal biopsy material. No toxin was found in urine or blood samples. Orellanine is rapidly concentrated in the kidneys in a relatively soluble form and cannot be detected in urine, blood and dialysis fluids at the time when first symptoms appear [42]. Consumption of mushrooms containing orellanine results in early symptoms as well, because of the presence of other toxins in addition to orellanine. Similar toxin with the same symptoms which show within 3–6 days has been isolated from *Amanita smithiana* [43].

Muscarine or **muscarin** (Figure 4) is a natural product of certain mushrooms like *Inocybe* and *Clitocybe* species and the deadly *C. dealbata* is a dangerous toxin. *Inocybe* and *Clitocybe* contain muscarine concentrations up to 1.6% [44].

Muscarine stimulates the muscarinic nerve and muscle receptors resulting in symptoms which include sweating, salivation, tears, blurred vision, palpitations. High doses could lead to respiratory failure. Muscarine is found in mushrooms of the genus *Omphalotus*, notably the Jack o'Lanterm mushrooms. It is also found in *A. muscaria*, although it is now known that the main effect of this mushroom is caused by ibotenic acid. Muscarine can also be found in some *Inocybe* species and *Clitocybe* species, in particular *Clitocybe dealbata*, and some red-pored *Boletes* [45].

Gyromitrin (Figure 5) is a toxin and carcinogen present in several members of the fungal genus *Gyromitra*, *G. esculenta*. It is unstable and is easily hydrolyzed to the toxic compound monomethylhydrazine, a component of some rocket fuels. Monomethylhydrazine acts on the central nervous system and interferes with the normal use and function of vitamin B_6. Poisoning results in nausea, stomach cramps, and diarrhea, while severe poisoning can result in convulsions, jaundice, or even coma or death. Exposure to monomethylhydrazine has been shown to be carcinogenic in small mammals.

The early methods developed for the determination of gyromitrin concentration in mushroom tissue were based on thin-layer chromatography and spectrofluorometry, or the electrochemical oxidation of hydrazine. These methods require large amounts of sample, are labor-intensive and unspecific. A 2006 study reported an analytical method based on gas chromatography-mass spectrometry with detection levels at the parts per billion levels. The method, which involves acid of gyromitrin followed by derivatization with pentafluorobenzoyl chloride, has a minimum detectable concentration equivalent to 0.3 microgram of gyromitrin per gram of dry matter. Gyromitrin causes severe gastrointestinal irritation, leading to vomiting and diarrhea. In some cases, liver failure has been reported [46].

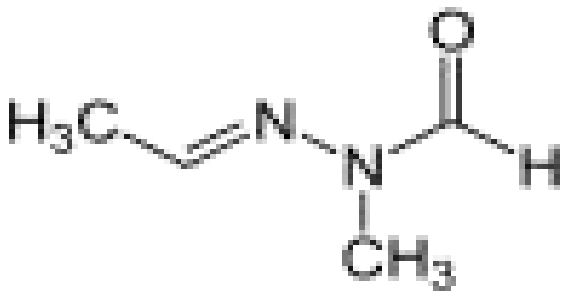

Figure 5: Chemical structure of gyromitrin [46].

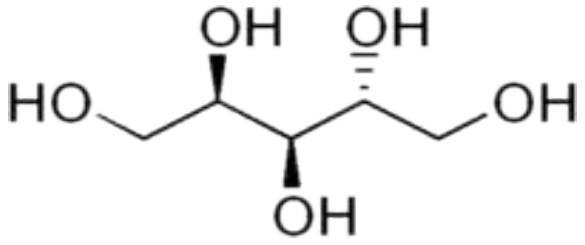

Figure 6: Chemical structure of arabitol.

Arabitol or **arabinitol** (Figure 6) is a sugar alcohol formed by the reduction of either arabinose or lyxose. It is similar to mannitol, which causes no harm in most people but causes gastrointestinal irritation in some. It is found in small amounts in oyster mushrooms, and considerable amounts in *Suillus* species and *Hygrophoropsis aurantiaca* (the "false chanterelle") [47,48]. Some organic acid tests check for the presence of D-arabitol may indicate overgrowth of intestinal microbes such as *Candida albicans* or other yeast/fungus species.

Traditional Methods of Distinguishing Poisonous From Edible Mushrooms

Traditionally, the ethno mycological knowledge of edible mushrooms is limited to their visible fruit bodies. Morphological identification is based on features such as cap color, cap shape, stipe color and shape, gills size and color of fruiting bodies which within a species can vary greatly depending on the environmental conditions, which often lead to errors in the determination of their species. Dimensional characteristics such as cap size and stipe length, the substratum they are attached to and spore growth are often used as distinguishing features. Other differences between poisonous and edible mushroom are presented in Table 3.

In a reported study [49] the Bado community of Kokrojhar district, BTAD Assam, India, has extensive mycological knowledge of easily differentiating the edibility of wild macrofungi. Indigenous knowledge of edible mushroom and their utilization by the locals is an important component of the ethno mycology [50]. Traditional mycological knowledge is acquired through oral transmission from generation to generation

There is general belief among most rural communities especially in Africa for distinguishing edible from poisonous mushroom. (1) A poisonous mushroom will turn silver black during cooking. (2) If the mushroom cap is peeled off, it is safe to eat. (3) When foraging animals consume a mushroom, then it is safe for humans to also consume. These generalizations do not give full assurance of safety. Traditionally, most edible mushrooms are known because someone ate it before and it was safe. This may not be a good way to recognize edibility of mushrooms since many species of both edible and poisonous mushrooms bear great resemblances.

There are inadequate accounts of traditional use of mushrooms in Africa. Accurate identification of mushroom is very important in their utilization by humans for consumption. Morphological identification which is traditionally common is prone to error, tedious and time consuming. More modern methods of identification are now employed by researchers to differentiate between mushroom species.

Table 2: Poisonous mushrooms and their effects on humans.

Toxin	Level of Toxicity	Effect when consumed
Alpha-amanitin	Deadly	Liver damage 1–3 days after ingestion. Principal toxin in genus *Amanita*.
Phallotoxin	Non-lethal	Gastrointestinal upset. Found in poisonous *Amanitas*.
Orellanine	Deadly	Kidney failure within 3 weeks after ingestion. Principal toxin in genus *Cortinarius*.
Muscarine	Potentially Deadly	Respiratory failure. Found in genus *Omphalotus*.
Gyromitrin	Deadly	Neurotoxicity, gastrointestinal upset, and destruction of blood cells. Principal toxin in genus *Gyromitra*.
Coprine	Non-lethal	Illness when consumed with alcohol. Principal toxin in genus *Coprinus*.
Ibotenic acid	Potentially Deadly	Neurotoxicity. Principal toxin in *Amanita muscaria*, *A. pantherina*, and *A. gemmata*.
Muscinol	Non-lethal	CNS depression and hallucinations. Principal toxin in *Amanita muscaria*, *A. pantherina*, and *A. gemmata*.
Psilocybin and psilocin	Non- Poisonous	CNS arousal and hallucinations. Principal effects in psilocybin mushrooms, many belonging to the genus *Psilocybe*
Arabitol	Non-lethal	Gastrointestinal irritation in some people
Bolesatine	Non-lethal	Gstrointestinal irritation, vomiting, nausea.
Ergotamine	Deadly	Affects the vascular system leading to loss of limbs and death. An alkaloid found in genus *Claviceps*.

Table 3: Differences between Poisonous and edible mushrooms [48].

Poisonous mushroom	Edible mushrom
When you cut the mushroom it turns either green or purple.	When you cut the mushroom it does not stain green or purple.
When you taste a piece of the mushroom, it burns or stings the tongue.	When you taste a piece of the mushroom, it does not burn or sting the tongue.
Poisonous mushrooms have bad odour.	Edible mushrooms have pleasant odour.
It tastes bitter.	It has sweet taste.
There is no presence of worms.	There is presence of worms.
There is presence of scales on the cap.	There is no scale on the cap.

In a molecular identification, Appiah et al [51] used genetic method to identify several mushroom species from Ghana. Similarly, 19 species of mushrooms were identified based on internet resources in Ekiti State, Nigeria out of which 11 species were edible and 8 inedible [52]. The biodiversity of mushrooms in Lagos State, Nigeria, was studied using modern biotechnological method of DNA sequence analyses [53].

Conclusion

Various mushrooms have been highly valued as food, as tonics and, in some cases, as medicine for a long period of time. Mushrooms have become more popular in recent years, as can be witnessed by the increased demands for higher production volumes. Their popularity is derived from three highly desirable characteristics as food: (I) they have remarkable taste and flavor; (2) they are nutritious, not only because they contain high contents of protein with significant amounts of lysine and methionine (which are low in plants), fibers, minerals, and vitamins, but also for what they do not have (high calories, sodium, fat, and cholesterol); (3) they can be easily processed, dried, pickled and canned to allow maximum storage and transportation

The ethno mycological knowledge among communities that forage mushrooms is based on oral communication handed down from generation to generation which is not a reliable safeguard. In countries where mushrooms are highly consumed, a number of intoxications are reported every year mainly due to misidentification of mostly wild species. Hazardous toxins are present in these species and are able to cause different syndromes that can be fatal depending on the amount ingested. Accidental ingestion of mushrooms is difficult to avoid especially in countries where eating wild species is common. Proper identification is important to avoid accidents and the identification of symptoms and signs of intoxication as soon as possible enables the success of treatment.

Recommendation

In using more advance and sophisticated tools in screening and testing the presence of other toxins aside from tryptamine and amatoxin should be done with actual amount to have more reliable results. Collection sites should be in a wider area to come up with more number of fungal organisms for identification. Proper handling of mushrooms and related species should always be done in a very careful manner to avoid poisoning. Mushroom gatherers should take precautionary measures in collecting mushrooms since in some species even inhalation of spores may cause immediate death. Mushroom gatherers should not take chances on gathering species of mushroom unknown to them. Pharmaceutical and nutritional efficacy for edible mushrooms is highly recommended.

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