Chapter 2
A Global Overview of Edible Mushrooms

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2.1 Introduction

Fungi are one of the most diverse and prominent organisms to inhabit and influence the earth. They are an essential component of ecosystem in recycling the mineral nutrients by acting as agents of decaying. Members of **Ascomycota** and **Basidiomycota**, under a precise combination of various abiotic conditions and surrounding flora are known to produce a detectable fruiting body called as "mushrooms" (Stojchev 1995). According to Chang and Miles (1992), "macrofungus are naked to eyes and are able to grow above ground (epigeous) and underground (hypogeous). They might have originated from ancient lineage ca. 400 million years ago and flourished in association with land plants as both saprobes and parasites (Boyce et al. 2007).

Considering the rich magnitude of fungal diversity, total of estimated mushroom diversity available to science is very less (Hawksworth 1991, 2001). While within reported mushrooms, only 50% (7000 species) acquire varying degrees of edibility; ≤ 3000 known species belongs to 31 different genera; ca. 1-10 % are poisonous mushrooms (Miles and Chang 1997). Mushrooms are recognized as rich sources of diverse bioactive principles that make them medically significant as theapeutic agents against pathogens, curing many health disorders and diseases (Wasser and Weis 1999; Lindequist et al. 2005; Ajith and Janardhanan 2007). Nevertheless many edible mushrooms have been integrated with human life since ancient times. **Mycophagy** is the act of consuming mushrooms. Hay (1887), a well-known British mycologist proposed the exclusive terms "mycophilia" and "mycophobia". Mycophilic societies refer to the peoples who like and appreciate mushrooms since ancient time. Mycophobic societies comprise of people showing aversion and fear

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towards mushrooms (Wasson and Wasson 1957). In general they have been used as food or food products by many tribal and urban peoples for their taste, dietary value with low calories and cholesterol but have high proteins content, minerals, fibres, good amount of vitamins and trace elements (Wani et al. 2010).

2.2 Ethnomycology

Ethnomycology gives details on WEF inculcated in our life since ancient times. Consequently, hallucinogenic mushrooms and their religious significance have been included under ethnomycology (Schultes 1940; Wasson 1968). Diverse areas of mushroom knowledge that includes entheogenics, cultivation, nutraceutics, **mushroom taxonomy**, mycophagy and mycopharmaceuticals are also represented by ethnomycological works (Wasser 2010).

According to Wasson (1971) (father of modern Ethnomycology), *Amanita muscaria* (divine mushroom of immortality) was used for scared rituals by "Aryans" over 4000 years ago (Fig 2.1). They believed that "Soma rasa", the vedic juice is believed to give divine qualities on the spirit of the consumer, even immortality. Traditionally, mushrooms have been used as food, medicine, poison and spiritual practices in religious rituals across the world since 5000 BC (Winkler 2008). The ethnomycological data of mushroom is well documented in various parts of the globe, especially in Asia (Kang et al. 2012, 2013; Pala et al. 2013), Africa (Oso 1975; Kinge et al. 2011), and Central America (Montoya-Esquivel 1998; Montoya-Esquivel et al. 2001).

Fig. 2.1 Stone carving of "'Weeping God" at Quetzalcoatl stone carving of Quetzalcoatl

Fericgla (1994) categorized different European peoples as eminently mycophilic. Ancient Greeks believed that consuming mushrooms offers stamina for soldiers in war and they named it as "sons of the gods," because of their mysterious appearance after thunderstorms. The ancient Romans believed mushrooms as "the food of the gods" and many Romanian writers made an attempt to explain significance of thunderstorms in the life cycle of fungi. Italian peoples are strongly mycophilic, but among the south Catalonia Sapnish community, the tradition of consuming WEF is less common. *Amanita caesarea* is known as "Caesar's mushroom" part of ancient Itlian cuisine, still it exits in many parts of county as a "*ovolo* or *ovolo buono"* or "fungo reale" (Reyna et al. 2002). Nowadays food menus were dominated by embracing diverse species of edible ones such as *Tuber* spp. (truffles) and *Boletus edulis* (porcini) in most of the European countries.

In 500 BC, Theophrastus defined truffles as "a natural phenomenon of great complexity with no stem, root, branch, fibre, leaf, bud or flower". Truffles are hypogeous fungi unique in its appearance served along with dessert only to pharaoh and royals (Trappe 1990). These hypogeous fungi were known to consume by ancient Babylonians, Etruscans, Egyptians, Greek and Romans (Tartufi 2011; Reyna and Garcia-Barreda 2014). At the eighteenth century, truffles regained its status in the cuisines of French and Italian people (Heim 1969). The truffles collected from the Muqattam hills were used only to grace the cuisines of "Fatimid Caliphates" in Egypt. Later, availability of large quantities of truffles in local markets of Cairo has made them cheaper that graced the common people food too (Trappe 1990).

Power et al. (2015) observed the spores from bolete and agaric mushrooms from the dental calculus of an adult woman from Magdalenian population (People of Paleolithic in Western Europe). Both agaric and bolete include many edible and medicinal mushrooms, this discovery could perhaps suggest the intentional consumption of fungi during Old Stone Age era which has not been reported earlier (Fig. 2.2).

Fig. 2.2 *Mushrooms Rock art at Selva Pascuala in Spain Credit: Juan Francisco Ruiz López*

Two fragments of a *Fomitopsis betulina* (formerly *Piptoporus betulinus*) basidiomata was found in Ötzi, a mummified Calcolithic Tyrolean body of an iceman who might have died 5300 years ago in an alpine glacier in the Val Senales glacier, Italy. This mushroom was known for its edibility and medicinal properties (Peintner et al. 1998). Ötzi, revealed the traditional knowledge and knowing of mushroom by ancient tribal people. Russians are well-known mycophilic group; duing weekend they had habit of collecting WEF from the forest (Filipov 1998). Russian's passion for mushroom was described among the Estonians by a saying: "Where there is a mushroom coming up, there is always a Russian waiting for it".

Mushrooms belong to the genus *Agaricus* and *Boletes* are not appreciated among African tribes for consumption, yet Europeans living in Africa habitually consume them (Rammeloo and Walleyn, 1993). From ancient period, ethnic people of Congo-Guinea basin have used edible mushrooms to supplement and diversify their diet (Buyck and Nzigidahera 1995). Dijk et al. (2003) documented three different edible species of cup-fungi (*Cookeina sulcipes* and *C. tricholoma*) and bird-nest's fungus (*Cyathus striatus*) which referred by a same name Tôloñg by Bantu and Bagyeli tribes of south Cameroon Tôloñg. In evident to this, *Peziza* was the common name used for both cup fungi and bird-nest's fungi in the mycological history of Europe. In many Slavic cuisines of Russians, mushroom holds a prominent status. Eskimos (Yupiks and Chukchi) consumed several species of wild *Leccinum*, *Lactarius, Russula* and *Armillariella* collected from Arctic Tundra (Yamin-Pasternak 2007, 2008).

Long net stinkhorns/ bamboo fungus is traditionally known for its consumption during the Mexican divinatory rituals because of its distinct shape. Tribals from New Guinea considered this fungus as sacred. The Urhobo and the Ibibio ethinic people from Nigeria used stinkhorns to prepare harmful charms (Oso 1975). Yekuana tribes, who are native to Amazon rain forest in Southern Venezuela, consumed two species *viz., Auricularia mesenterica* and *Polyporus* sp. (Chitty 1992). In Chile, WEF were seems to be part the food or cuisine about 13000 years ago (Rojas and Mansur, 1995).

China is a distinctive example of a mycophilic soceity when compared to other countries. According to the archaeological documentation, edibility of wild fungi is first well renowned in China even before the birth of Christ (FAO 1998). Paddy straw mushroom (*Volvariella volvacea*) a common edible mushroom has been cultivated in China during eighteenth century (Chang 1977). Later, it was cultivated in other South Asian countries during 1932 to 1935, (Baker 1934; Chang 1974). Ethnic tribes from Nepal believed that the mushrooms found in high-altitude areas were related to lack of toxicity. Christensen et al. (2008) supported this observation by confirming the frequency of poisonous mushrooms in the *Pinus wallichiana* forest compared to the forest types at lower altitudes was very low. Their study also noted that, there are no known poisonous mushrooms looking like the frequently eaten ones in the high-altitude forests. The first documentation of Yarsagumba (Caterpillar fungus or *Cordyceps*) was by a Tibet physician who described the importance of the mushroom as a "sexual tonic" in his text entitled "An Ocean of Aphrodisiacal Qualities". From ancient times, *Cordyceps sinensis* has been described in old

Chinese and Tibetan medicinal books. Many tribes store mushrooms for future use by drying them in porous baskets or outdoors in structures similar to granaries (Beals 1933; Maniery 1983).

The significant cultural values of wild edible mushrooms diverge across the world. In Indian ayurveda, mushrooms were kept under "tamasika ahara" (Tamasic diet) along with meat of an animal, fish, the fertilized egg, onion, garlic etc., which were believe to cause certain potentially physical conditions and also as a medicine for enhancing energy and vitality (Saddler 2003). Wild edible mushrooms and ethno-mycological practices of the wild mushrooms have been documented by several authors from North-East Indian states (Boruah et al. 1996; Sing et al., 2002). *Morchella* spp. (Ascomycotas) generally recognized as morels and 'Guchhi' in the Indian market are well known for its edibility (Lakhanpal et al. 2010). The local community in Northwestern Himalaya used common names for many of the wild mushrooms which, suggest that they have a practice of utilizing it for a very long period. Semwal et al. (2014) documented some of those wild edible mushrooms from Northwestern Himalaya. Traditionally in India, mushroom collection is known to be the final alternative for poor people in lean periods (Harsh et al. 1993); Chinese and Mexicans often offered mushrooms as gifts owing to their nutritional values (Härkönen 2002; Garibay-Orijel et al. 2007). Because of the fact that habitats include decaying matter and fear of poisoning these wild mushrooms are avoided religiously (Härkönen 2002; Walleyn and Rammeloo 1994). Numerous tribes belonging to the Nahua speaking Indians of Mesoamerica used psychoactive fungus (*Psilocybe*) in magico-religious ceremonies as divinatory sacraments (Schultes 1939, 1940; Wasson and Wasson 1957).

Britain is usually classified as mycophobic. While Castilian or Valencian of Spain also considered as mycophobic society. Mycophilic immigrants and commercial reasons have changed attitudes of **mycophobic community**. For example, now, there are an increasing number of Americans people who collect WEF in the forest (Dyke and Newton 1999). However variations among these societies still exist widely in different parts of the world. Variable traditions also exist in the United Republic of Tanzania (Härkönen et al. 1994a, b). This clearly indicates that mushroom collection was found to be more common among the tribes who lived in high-altitude forest areas which are important part of their diet and provide income when they started selling in local markets.

2.3 Common Wild Edible Mushroom

WEF are non-timber forest resource well documented in many parts of the world. Of the 1.5 million estimated fungi, only 14000 nos. were described across the world (Chang and Miles 2004). About 7000 mushrooms (50%) possess varying degree edibility and 3000 from 31 genera are potentially edible but 10% are known to be lethal (Chang and Miles 1996). Boa (2004) compiled over 200 genera of macrofungi which contains species that are either consumed directly as food or are used

indirectly for health benefits. Some common edible species are *Agaricus, Auricularia, Dictyophora, Flammulina, Hericium, Lentinula, Pholiota, Pleurotus, Tremella* and *Volvariella* have been consumed across the world. But there are species that are highly esteemed such as *Cantharellus*, *Sparassis*, *Lactarius*, *Suillus, Tuber* and *Morchella*. Often there are species that are eaten in a region or country which are consider harmful or poisonous by others e.g. *Agaricus arvensis, A. semotus, Amanita gemmate, Coprinus atramentarius,* and *Lenzites elegans* (Lincoff and Mitchel 1977; Logemann et al. 1987; Rammeloo and Walleyn 1993 and Chang and Mao 1995). In developing countries, WEF are the source of food and medicine (Cakilcioglu et al. 2011) and provides additional income.

In the recent years, the nomenclature and identification has step up with the molecular characterization of mushroom, thus knowing the scientific name of a mushroom highly increase the chance of identifying its edibility. Garibay-Orijel et al. (2006) reported about 300 wild edible mushroom has been consumed by rural people of Mexico and ca. 180 species were known to be potentially edible mushrooms (Cordova et al. 2002). In some cases, knowing the genus alone suffices its edibility for example; all known species of *Cantharellus* are edible (Boa 2004). *Tuber* sp., generally known as truffles is considered one of the costliest mushrooms, particularly in the Northern European counties. Few desert truffles like *Terfezia* and *Tirmania* are endemic in arid and semi-arid areas of the Mediterranean (Hall et al. 2007).

Following are some of the important genera that are consumed worldwide (Iordanov et al. 1978; Saenz et al. 1983; Bon 1987; Zang 1988; Rammeloo and Walleyn 1993; Buyck 1994; Chang and Mao 1995; Degreef et al. 1997; Hall et al. 1998a, b; Jordan 2000; Boa 2004; Thawthong et al. 2014; Zhang et al. 2015;):

1. ***Agaricus***: The genus *Agaricus* is an important source of food and medicine, hosting over 434 species worldwide, of which about 60 species are reportedly eaten in 29 countries. *Agaricus* L. includes economically important species like *A. bisporus*, commonly known as the button mushroom (Cappelli 1984; Kerrigan 1986; Largeteau et al. 2011). It's considered as the most widely cultivated edible species of mushrooms with over 32 % of the total mushroom production, worldwide. Some of the edible species includes; *A. arvensis, A. aurantiacus, A. bingensis, A. bisporus, A. bulbillosus, A. blazei, A. campestris, A. comptulus, A. croceolutescens, A. endoxanthus, A. erythrotrichus, A. gennadii, A. goossensiae, A. maculatus, A. micromegethus, A. nivescens, A. placomyces, A. purpurellus, A. rodmani, A. semotus, A. sylvicola, A. silvaticus, A. subedulis, A. subperonatus, A. subrutilescens, A. volvatulus*. Others species were not well accepted but commercially cultivated species includes; *A. arvensis, A. campestris, A. bitorquis* and *A. subrufescens*. Few species are reported to be poisonous for example *A. xanthodermus, A. litoralis.*
2. ***Amanita*:** There are about 83 edible species reported from 31 countries (Boa 2004). *A. caesarea* is highly valued and one of the most highly sought mushroom worldwide (Boa 2004; Wang and Chen 2014) especially in Mexico, Nepal and Turkey. Some of the edible species consumed worldwide are*; A. argentea, A.*

aurea, A. bingensis, A. caesarea, A. calopus, A. calyptratoides, A. calyptroderma, A. ceciliae, A. craseoderma, A. crassiconus, A. crocea, A. flammeola, A. flavoconia, A. gemmate, A. goossensiae, A. hemibapha, A. hovae, A. inaurata, A. loosii, A. masasiensis, A. muscaria, A. perphaea, A. rubescens, A. robusta, A. subviscosa, A. spissa, A. strobilaceovolvata, A. tuza, A. fulva, A. virgineoides, A. vaginata, A. umbonata, A. xanthogala and *A. zambiana* (Simmons et al. 2002; Flores et al. 2002). Few of this species are exported and traded. Some species of *Amanita* have conflicting reports on edibility for example *A. gemmata* reportedly edible in Mexico and Costa Rica while in Guatemala the species was reported with case of poisoning like-wise, in *A. flavoconia* and *A. spissa* (Logemann et al. 1987; Chang and Mao 1995). Some species are highly poisonous for example *A. phalloides,* which is popularly called as "death cap" known for more number of deaths after consuming it (Lincoff and Mitchel 1977; Liu and Yang 1982; Boa 2004).

3. ***Auricularia***: This genus is known by their several common names; ear fungi, Judas's ear, Jew's ear, jelly ear, black jelly etc., and distributed throughout the temperate and subtropical regions worldwide (Ingold 1985; Du et al. 2011). There are about 13 edible species reported from 24 countries. Many Southeast Asian countries like China, Taiwan, Thailand, Philippines Indonesia and Malaysia are into cultivation of this Ear fungus. However, China alone produces about 3.6 million tonnes per year that is 6% of the total world's production. *A. auricula* and *A. polytricha* are widely considered to be the earliest cultivated mushroom dating back 600 A.D. China (Lou 1978; Quimio 1979; Li 2012). Some of the other edible species consumed worldwide are; *A. auricula-judae, A. cornea, A. delicata, A. fuscosuccinea, A. mesenterica, A. polytricha* and *A. tenuis,* (Prance 1984; Flores 2002).
4. ***Boletus****:* About 72 edible species have been reported from over 30 countries (Boa 2004). The common species, *B. edulis,* known by several names (king bolete, *porcini, suilli, penny buny, panza etc.*) is an ecologically and economically important species consumed worldwide (Arora Arora and Dunham 2008; Feng et al. 2012). Yugoslavia was the highest exporter during 1993–1995, producing a maximum of 5186 tonnes in 1993. In the South Africa, *B. edulis* were introduced to the native forest with the plantation of exotic trees; however the locals were skeptical of consuming the unknown variety (Boa 2004). In China, families living in the mountain areas, exploited *B. edulis* and sold them in farmers market to overcome financial insecurity (Zhang et al. 2017). *B. edulis* was popularly consumed in countries like; Europe, North America and Asia (Agueda et al. 2008). Other edible species consumed worldwide are; *B. aereus, B. aestivalis, B. appendiculatus, B. aurantiacus, B. atkinsonii, B. barrowsii, B. bicoloroides, B. bouriqueti, B. bulbosus, B. calopus, B. caudicinus, B. citrifragrans, B. colossus, B. communis, B. crassus, B. cyanescens, B. elegans, B. emodensis, B. erythropus, B. felleus, B. frostii, B. griseus, B. impolitus, B. loyo, B. luridus, B. luridiformis, B. michoacanus, B. nigroviolaceus, B. pseudoloosii, B. pinicola, B. pinetorum, B. pinophilus, B. rubellus, B. regius, B. reticulatus, B. russellii, B. scaber, B. subtomentosus, B. sulphureus, B. speciosus, B. truncatus, B. variega-*

tus, B. variipes, B. violaceofuscus, B. vitellinus and *B. zelleri* (Bouriquet 1970; Vasilèva 1978; Malyi 1987; Adhikari and Durrieu, 1996; Montoya-Esquivel 1998; FAO 1998; Hall et al. 1998a, b; Ereifej and Al-Raddad 2000; Montoya-Esquivel et al. 2001; Sabra and Walter 2001).

5. ***Cantharellus***: *Cantharellus* spp. are ectomycorrhizal fungi, about 22 edible species reported from 45 countries with a good reputation for edibility (Buyck 2008; Arora and Dunham 2008). The species are commonly known for their fruity, apricot-like odour with diverse species distributed throughout the world. Most common species, *C. cibarius* popularly known as golden chanterelle, is a highly commercial species which is harvested from nature alone. As these mushrooms are mycorrhizal and haven't been mass cultivated successfully but procuring from the local sellers will be expensive (Hall and Zambonelli 2012; Yun and Hall 2004). There are no known poisonous species. Some species are very common in the markets of many countries and are sold in mixture of different species. Some edible species spread across the world are; *C. cibarius, C. cinereus, C. cinnabarinus, C. congolensis, C. cyanescens, C. cyanoxanthus, C. densifolius, C. eucalyptorum, C. floccosus; C. floridulus, C. formosus, C. ignicolor, C. incarnatus, C. infundibuliformis, C. isabellinus, C. longisporus, C. luteocomus, C. luteopunctatus, C. lutescens, C. madagascariensis, C. miniatescens, C. minor, C. odoratus, C. platyphyllus, C. platyphyllus, C. pseudofriesii, C. pseudocibarius, C. ruber, C. rufopunctatus, C. splendens, C. symoensii, C. subalbidus, C. subcibarius, C. tenuis* and *C. tubaeformis* (Bouriquet 1970; Buyck 1994; Härkönen et al. 1994a; Adhikari and Durrieu 1996; Adhikari 1999; Tedder et al. 2002; Flores 2002).
6. ***Clitocybe***: This genus is estimated to have ca. 1131 associated species. However, only a few members of this genus considered as edible and others as toxic or poisonous. Although, the genus is better known for its toxicity (not as deathly), some species have proven to be beneficial in medical aspect. For example *Clitocybe nebularis* (Pohleven et al. 2009), *Clitocybe maxima* (Zhang et al. 2010) and *C. alexandri* (Vaz et al. 2010). *C. clavipes, C. fragrans, C. geotropa, C. gibba, C. hypocalamus, C. infundibuliformis, C. nebularis, C. odora, C. squamulosa* and *C. suaveolens* are few examples of edible species reported from various parts of the world including; Australia, Bulgaria, Chile, China, Hong Kong, India, Indonesia, Mexico, Russia and Ukraine (Burkhill 1935; Vasilèva 1978; FAO 1998).
7. ***Cordyceps***: It's a unique Ascomycetous genus grows on the larva of insects. About 37 edible species have been reported from three countries. Although edible species are consumed only for their health benefits, while many species has been described from Japan, they are intensively collected in parts of China and Nepal. *C. cicadicola, C. gunnii, C. liangshanensis, C. ophioglossoides, C. militaris* and *C. sinensis* are some valued species for their medicinal property (Hall et al. 1998a, b; Gong and Peng 1993; Yang et al. 2009). *C. militaris* is medicinally important species with beneficial properties such as antioxidant (Chen et al. 2013; Jiang et al. 2011), **antitumor**, **anti-inflammatory** and **immunomodulatory** and effects (Hsu et al. 2008; Jiang et al. 2011; Bai and

Sheu 2018). Localities collect these mushrooms to overcome the finacinal needs. Due to the anthropological effects and habitat loss, the ecosystem of *C. sinensis* has been affected which ultimately declined the natural yield.

8. ***Cortinarius***: There are about 30 edible species reported from over 11 countries. In Europe and North America, *Cortinarius* spp. is less popular due to the incidences associated with poisonous species. An example, *C. orellanus* was responsible for a total count of 11 dead in the year 1952 (Lincoff and Mitchel 1977; Lampe and Ammirati 1990). Only a few edible species have been reported from countries such as Costa Rica, China, Japan, Russia and Ukraine. The edible species includes; *C. alboviolaceus, C. armeniacus, C. armillatus, C. claricolor, C. claricolor var. turmalis, C. cornucopioides, C. collinitus, C. crassus, C. elatior, C. glaucopus, C. largus, C. mucosus, C. multiformis, C. orichalceus, C. praestans, C. purpurascens, C. rufo-olivaceus, C. varius* (Vasilèva 1978; Liu and Yang 1982; Zang 1984; Chamberlain 1996; Montoya-Esquivel et al. 2001).
9. ***Flammulina***: *F. velutipes,* popularly known "golden needle mushroom" was ranked fifth in the year 1997 for a total worldwide production of edible mushrooms in Southeast Asian counties like China, Japan, Korea, and Taiwan (Kües and Liu 2000; Psurtseva 2005). Till 1977 *Flammulina* was considering monotypic genus which was separated into two species namely; *F. ononides* and *F. velutipes*. Later, several species were reported from across the world and base on their authentic descriptions, 14 species has been accepted under this genus however information on their edibility is very limited (Redhead and Perterson 1999; Perez and Fernández 2007; Bas, 1983; Ge et al. 2008 and Ge et al. 2015).
10. ***Laccaria***: Nine edible spp. are reported from 17 countries. Common species is *L. lacata* found in North temperate countries such as Europe, North America, Mexico and Costa Rica (Chamberlain 1996; Tedder et al. 2002). This genus is mycorrhizal thus cultivation is not promising however wild mushrooms are collected and sold in the local markets (Boa 2004). Some of the edible species consumed worldwide are: *L. amethystea, L. amethystina, L. amethysteo- occidentalis, L. bicolor, L. edulis, L. farinacea, L. laccata, L. proxima* and *L. scrobiculatus* (Lopez et al. 1992; Tedder et al. 2002; Flores 2002).
11. ***Lactarius***: There are about 94 edible species reported from over 39 countries. All species of *Lactarius,* when fresh, are characterized by the unique ability to produce a milky fluid, if cut or broken. The color and taste of the milk varies between the species and are considered of great taxonomical value (Athanasakis et al. 2013). They are widely distributed, from Asia, America to Europe (Flores et al. 2002). In Spain, particularly in Palencia, *L. deliciosus* are a valuable mushroom which is sold at 2 € per kg and about 4000 kg are marketed on a daily basis during season (Roman and Bao 2004). China produces around 308000 tons of *L. deliciosus* annually (Sun and Xu 1999) while Estonia produces over 250 tons of *L. rufus* (Kalamees and Silver 1988). *L. piperatus* (peppery milk-cap; currently placed under the genera *Lactifluus*) and *L. torminosus* (woolly or bearded milk-cap) were reported to be edible and included in Turkish cuisines (Malyi 1987; Caglarirmak et al. 2002) but former is reported as poisonous in China (Liu and Yang 1982). Some edible species include; *L. akahatsu,*

L. angustus, L. annulatoangustifolius, L. camphoratus, L. carbonicola, L. chrysorrheus, L. congolensis, L. controversus, L. corruguis, L. deliciosus, L. denigricans, L. densifolius, L. edulis, L. flavidulus, L. gymnocarpoides, L. gymnocarpus, L. hatsudake, L. heimii, L. indigo, L. insulsus, L. inversus, L. lapponicas, L. kabansus, L. laevigatus, L. laeticolor, L. latifolius, L. luteopus, L. medusae, L. mitissimus, L. necator, L. pelliculatus, L. phlebophyllus, L. piperatus, L. princeps, L. pseudovolemus, L. pubescens, L. pyrogalus, L. quietus, L. resimus, L. rubidus, L. rubrilacteus, L. rubroviolascens, L. rufus, L. salmonicolor, L. sanguifluus L. scrobiculatus, L. sesemotani, L. subdulcis, L. subindigo, L. tanzanicus, L. torminosus, L. trivialis, L. vellereus, L. volemoides, L. volemus, L. xerampelinus, L. yazooensis and *L. zonarius* (Bouriquet 1970; Vasilèva 1978; Härkönen et al. 1994b; Adhikari and Durrieu 1996; Namgyel 2000; Demirbas 2000; Montoya- Esquivel et al. 2001; Deschamps 2002; Caglarirmak et al. 2002; Lian et al. 2007).

12. ***Leccinum***: There are about 14 edible species widely collected and consumed in Europe and New Zealand (Boa 2004). The species *L.* versipelle popularly collected in Poland and highly valued when fresh but not as much when dried (Guminska and Wojewoda 1985). Some edible species reported across the world are; *L. aurantiacum, L. chromapes*, *L. extremiorientale, L. griseum, L. holopus, L. lepidum, L. manzanitae, L. oxydabile, L. rugosiceps, L. scabrum, L. testaceoscabrum* and *L. versipelle* (Lincoff and Mitchel 1977; Vasilèva, 1978; Malyi 1987; Walleyn and Rammeloo 1994; Mafinez et al. 1997).
13. ***Lentinula***: There are only about three edible species reported from six countries. *L. edodes* popularly known as "shiitake" and is one of the most cultivated mushroom worldwide especially South East Asia (Reshetnikov et al. 2001). In 1986, worldwide production of *L. edodes* was 14% (Chang and Miles 2004). Species such as *L. boryana, L. edodes, L. lateritia* are edible, reported from Chile, India, Mexico, Nepal, Papua New Guinea and Thailand (Purkayastha and Chandra 1985; Jones et al. 1994; Sillitoe 1995; Schmeda et al. 1999; Adhikari 1999).
14. ***Lentinus***: There are about 28 edible species reported from over 24 countries (Boa 2004). Most species of *Lentinus* are edible, but few species with their tough texture are of less significant. The edible species such as; *L. sajor-caju* and *L. strigosus,* are important species possessing anti-oxidant property (Yang et al. 2002). *L. araucariae, L. brunneofloccosus, L. crinitus, L. glabratus, L. sajor-caju, L. strigosus, L. squarrosulus, L. tuber-regium, L. velutinus,* are few edible species reported from Benin, Brazil, Burundi, Central Africa, China, Congo, Ethiopia, Gabon, Ghana, India (Zang 1984; Prance 1984; Rammeloo and Walleyn 1993; Buyck 1994; Kalotas 1997; Obodai and Apetorgbor 2001).
15. ***Lepista***: Commonly called "blewit mushroom", a wild edible mushroom (Eyüpoğlu et al. 2011). They are found throughout mainland of Europe and in many other parts of the world including North America. They are very important economically, and are cultivated by Mushroom Research Center in France (Suberville et al. 1996), but cultivated wood blewit mushrooms are not delicious compared to wild wood blewit mushrooms (Barutçiyan 2012). Wood ble-

wits are collected for their medicinal uses. They are highly nutritious containing 44.2% crude protein, 9.0% lipids, 5.4% ash and 41.4 % carbohydrates (Colak et al. 2007). Medicinal uses includes; prevention against beriberi (Dulger et al. 2002), antimicrobial, antioxidant properties (Pinto et al. 2013). Some of the *Lepista* spp. consumed throughout the world are; *L. caespitosa; L. caffrorum, L. dinahouna, L. glaucocana, L. irina, L. luscina, L. nuda, L. personata* and *L. sordida,* (Hall et al. 1998a, b).

16. ***Lycoperdon***: About 22 edible species are reported from over 19 countries (Boa 2004). The genus is distributed worldwide; Common species are *Lycoperdon giganteum, L. pyriforme* and *L. perlatum* popularly known as puffballs, one of the biggest edible mushrooms with size reaching up to 150 Cm in diameter (John et al. 2011). Habitat to woods, grassy areas, and along roads. However, *L. perlatum* looks similar to immature fruit bodies of poisonous *Amanita* spp. (Lassoe et al. 1996). Some edible species are *L. asperum, L. candidum, L. endotephrum, L. echinatum, L. gemmatum, L. marginatum, L. oblongisporum, L. peckii, L. perlatum, L. pyriforme, L. pusillum, L. rimulatum, L. spadiceum, L. umbrinum, L. umbrinum var. floccosum* reported from countries such as Banin, Bhutan, Bulgaria, Canada, China, India, Kyrgyzstan, Madagascar, Mexico (Elćhibaev 1964; Harsh et al. 1996; Namgyel 2000; Lian et al. 2007), *L. asperum, L. pusillum, L. perlatum, L. pyriforme, L. spadiceum,* are used as medicine in China (Chang and Mao 1995).
17. *Macrolepiota*: There are about 13 edible species from over 33 countries. The common species *M. procera* traded in small scale; they have high nutritional values and are consumed all over the world (Boa 2004). *Chlorophyllum molybdites* a species with conflicting report of poisonous mushroom is often confuse with *M. procera*. Few worldwide distributed edible species worldwide are: *M. africana, M. dolichaula, M. excoriata, M. excoriata var. rubescens, M. gracilenta, M. gracilenta var. goossensiae, M. procera, M. prominens, M. procera var. vezo, M. puellaris, M. rhacodes* and *M. zeyheri* (Elćhibaev 1964; Bouriquet 1970; Vasilèva 1978; Saenz et al. 1983; Purkayastha and Chandra 1985; Adhikari and Durrieu 1996; Degreef et al. 1997; FAO 1998; Tedder et al. 2002). *M. neomastoidea,* distributed throughout Korea and other East Asian countries is reported to be poisonous (Kim et al. 2009).
18. ***Morchella***: There are about 62 reported species from over 28 countries (Boa 2004; Negi 2006). *M. esculenta* is well known species which are consumed by the people but are also known for their toxicity when eaten raw forms (Lincoff and Mitchel 1977). The species *M. esculanta* is among the most highly prized and morphologically recognizable fungi in the world (Goldway et al. 2000). In Turkey, this species cost around 130 euro/kg. (Okan et al. 2013). They are diverse and found worldwide. Some of the edible species are: *M. angusticeps, M. conica, M. conica var. rigida, M. costata, M. crassipes, M. deliciosa, M. elata, M esculenta, M. esculenta var. rotunda, M. esculenta var. umbrina, M. esculenta var. vulgaris* and *M. intermedia* (Singh and Rawat 2000; Deschamps 2002).
19. ***Pleurotus*:** There are about 40 edible species reported from over 35 countries (Boa 2004). *P. ostreatus* most widely consumed popular species; commonly

known as oyster mushroom. They are cultivated in many parts of the world so *P. ostreatus* production was at 14.2 % of the total WEF produced worldwide (Chang 1999). Some of the species consumed around the world are; *P. abalonus, P. citrinopileatus, P. cornucopiae, P. cystidiosus, P. concavus, P. djamor, P. eryngii, P. floridanus, P. pulmonarius, P. ostreatus, P. rhodophyllus, P. spodoleucus, P. sapidus* and *P. salignus* (Zang 1984; Buyck 1994; Chamberlain 1996; Namgyel 2000).

20. ***Podaxis***: They appear like a stalked-puffball and are secotioid fungi in Agaricaceae which comprises about 44 species (Conlon et al. 2016). *P. pistillaris* is common edible species under this genus commonly reported from Afghanistan, Australia and Hawaiian Islands. Besides their use as food (Abraham et al. 2017), they are also used as hair dye in Australia (Batra 1983) and as baby-powder in West Africa (Gérault and Thoen 1992). In India and Pakistan, *P. pistillaris* species was reported to be edible (Batra 1983) but they were reported poisonous by Nigeriens (Walleyn and Rammeloo 1994).
21. ***Polyporus***: There are about 30 edible species reported across 20 countries. Many species are reportedly used as remedial medicine or are eaten but are relatively of minor importance (Boa 2004). Some of the edible species reported from around the world are; *P. aquosus, P. alveolaris, P. arcularius, P. badius, P. brumalis, P. blanchettianus, P. brasiliensis, P. confluens, P. croceoleucus, P. elegans, P. eucalyptorum, P. fimbriatus, P. grammocephalus, P. indigenus, P. moluccensis, P. mylittae, P. rhizomorphus, P. rugulosus, P. sapurema, P. stipitarius, P. squamosus, P. sanguineus, P. tricholoma, P. tubaeformis, P. tenuiculus, P. tinosus, P. tuberaster* and *P. umbellatus,* (Burkhill 1935; Bouriquet 1970; Prance 1984; Remotti and Colan 1990; Walleyn and Rammeloo 1994; Chang and Mao 1995; Sillitoe 1995; Adhikari and Durrieu 1996; Kalotas 1997; Hall et al. 1998a, b; Adhikari 1999; Härkönen 2002).
22. ***Ramaria***: There are about 44 edible species reported from over 18 countries. Several major species are regularly collected and sold in markets of Nepal and Mexico, of which *R. botrytis* are the most popularly consumed species (Boa 2004). In Nepal, *R. formosa* is considered as edible while in Bulgaria, it was treated as poisonous (Iordanov et al. 1978; Adhikari and Durrieu 1996). Some of the edible species collected worldwide are; *R. araiospora, R. apiculata, P. aurea, R. bonii, R. botrytoides, R. botrytis, R. cystidiophora, R. flava, R. flavobrunnescens, R. mairei, R. ochracea, R. obtusissima, R. rosella, R. rubiginosa, R. rubripermanens, R. subaurantiaca, R. stricta, R. sandaracina, R. sanguinea* and *R. subbotrytis* (Liu and Yang 1982; Walleyn and Rammeloo 1994; Chamberlain 1996; FAO 1998; Montoya-Esquivel 1998; Flores 2002).
23. ***Russula***: Nearly, 128 edible species has been repoted over 28 countries (Boa 2004). *R. emetic* is eaten by Mexicain and Russian but otherwise believe to be poisonous when eaten uncooked (Vasilèva 1978). *Russula* is mycorrhizal fungi, so very difficult to bring into cultivation and it is highly diverse. Some of the edible specie includes: *R. alutacea, R. atrovirens, R. atropurpurea, R. chamaeleontina, R. cyclosperma, R. cyanoxantha, R. cellulata, R. compressa, R. congoana, R. diffusa* var. *diffusa, R. delica, R. depallens, R. emetic, R. lepida, R.*

erythropus, R. grisea, R. hiemisilvae, R. meleagris, R. minutula, R. oleifera, R. olivacea, R. pectinata, R. pseudopurpurea, R. phaeocephala, R. pseudostriatoviridis, R. roseoalba, R. roseostriata, R. rubra, R. sesenagula, R. striatoviridis, R. testacea, R. vesca, R. virescens, R. viscida and *R. xerampelina* (Liu and Yang 1982; Buyck 1994; Degreef et al. 1997; Tedder et al. 2002).

24. ***Suillus***: There are about 27 edible species reported from over 25 countries. *S. luteus* is the common species collected and consumed worldwide; major collectors have been from Argentina, Ecuador and Chile (Hedger 1986). *S. granulatus*is is another species widely recorded edible and a good source of carbohydrate and minerals (FAO 1998). The species *S. placidus* are considered edible in Russia, however poisonous in China (Vasilèva 1978; Chang and Mao 1995). Estonia and Mexico, in the late 80's, were the leading producers of *Suillus* spp. producing about 280 kg/ha in total (Villarreal and Guzmán 1985; Kalamees and Silver 1988). Some of the important species includes: *S. abietinus, S. acidus, S. americanus, S. bovinus, S. brevipes, S. cavipes, S. granulatus, S. grevillei, S. hirtellus, S. luteus, S. lactifluus, S. pictus, S. placidus, S. plorans, S. pungens, S. pseudobrevipes, S. subluteus, S. tomentosus, S. variegatus* and *S. viscidus* (Lincoff and Mitchel 1977; Vasilèva 1978; Namgyel 2000; Montoya-Esquivel et al. 2001).
25. ***Sparassis***: *S. crispa* is popular edible species commonly known as Cauliflower mushroom. They are ectomycorrhizal fungus associated with coniferous forest from the mountains of Eastern Asia, Europe and North America (Humpert et al. 2001; Adhikari et al. 2005). However, they are also collected in countries such as; Canada, China, India, Mexico, Russia, Turkey, Ukraine, USA (Vasilèva 1978; Purkayastha and Chandra 1985; Hall et al. 1998a, b; Tedder et al. 2002). While, *S. crispa* are known for their edibility, they are more popularly known for their medicinal properties (Kawagishi 2007; Kwon et al. 2009; Kimura 2013; Elsayed et al. 2014).
26. ***Terfezia***: They are generally called as "desert truffles" native to arid and semi-aridlands of Mediterranean countries, parts of Asia, Europe, North America, North and South Africa. *T. claveryi* and *T. areanaria* are the popular species and very expensive in Europe. They are served as a major course in high-class restaurants; while in the countries of Middle East and Gulf, North Africa, this mushroom are eaten raw (Fortas and Chevalier 1992; Bradai et al., 2015). There are about 7 edible species reported from over eight countries which includes; *T. boudieri, T. claveryi, T. decaryi, T. pfeilii, T. leonis, T. arenaria, T. leptoderma* (Bouriquet 1970; Al-Naama et al. 1998; Martinez et al. 1997; FAO 2001; Sabra and Walter 2001).
27. ***Termitomyces***: It is known to be extremely esteemed genus with high nutritional values e.g. *T. clypeatus* possess a significant quantity of nutrients (Ogundana and Fagade 1982, Tibuhwa 2012). There are about 27 edible species reported from over 35 countries (Boa 2004) with world largest species, *T. titanicus.* They are more prevalent in usage among Africans and Asians, still poorly documented (Pegler and Vanhaecke 1994). *T. clypeatus* are collected and sold by the local markets of Tibet, Nepal and Northern India (Harsh et al.

1996). Notable edible species include: *T. aurantiacus, T. albuminosus, T. clypeatus, T. cylindricus, T. eurrhizus, T. entolomoides, T. fuliginosus, T. globulus, T. heimii, T. le-testui, T. mammiformis, T. medius, T. microcarpus, T. robustus, T. schimperi, T. striatus, T. titanicus* (Pegler and Vanhaecke 1994).

28. ***Tricholoma***: There are about 57 edible species reported from over 30 countries (Boa 2004). *T. matsutake* is the most valued and expensive species (Hall et al., 1998). *T. matsutake* are exported mostly from countries such as Bhutan, China, Koreas and Russia (Yeh 2000; Namgyel 2000; Winkler 2002) as such in China a '*T. matsutake'* farmers income is slated around 5 – 6 million USD per annum (Winkler 2002). While *T. pessundatum* are believed to be poisonous (Lincoff and Mitchel 1977) but it has been consumed in Hong Kong (Chang and Mao 1995). The edible species includes; *T. caligatum, T. columbetta,, T. equestre, T. flavovirens, T. georgii, T. imbricatum, T. magnivelare, T. matsutake, T. mauritianum, T. mongolicum, T. nauseosum, T. personatum, T. pessundatum, T. portentosum, T. quercicola, T. russula, T. rutilans, T. saponaceum,T. scabrum, T. sejunctum, T. sulphureum, T. terreum, T. tigrinum, T. ustaloides* and *T. vaccinum,* (Liu and Yang 1982; Purkayastha and Chandra 1985; Malyi 1987; Kytovuori 1989; Chang and Mao 1995; Hall et al. 1998b; Namgyel 2000; Tedder et al. 2002; Winkler 2002).
29. ***Tuber*:** There are about 18 edible species reported from eight countries (Boa 2004). Edible species such as; *T. aestivum* (black truffle), *T. borchii* (white truffle), *T. brumale* (black truffle), *T. indicum* (black truffle), *T. magnatum* (white truffle) and *T. melanosporum* (black truffle). These are few popular species which are widely studied. Some of these species are sold at a very high rate costing around 600 to 6000 € per kg (Luard 2006). *T. indicum* is one of the renowned commercial truffles in Yunnan Province, China and it has been exported to Japan, United States, Europe and Australia since the 1980's (Tao and Liu 1990). Truffles are known for their variety of aromatic property and thus appeals differently from person to person for example; *T. melanosporum* have an aroma of 'wet forest' in between the taste of a radish and a tint hazelnut, while the *T. magnatum* gives an aroma of garlicky cheese with subtle methane overtones (Cullere et al. 2009). *Tuber* spp. have been reported from all over the world; edibles species includes; *T. aestivum, T. borchii, T. brumale, T. californicum, T. gibbosum, T. hiemalbum, T. indicum, T. melanosporum, T. magnatum, T. mesentericum, T. moschatum, T. oligospermum, T. rufum* and *T. sinosum* (Zang and Pu 1992; Hall et al. 1998a; Sabra and Walter 2001; Moreno-Arroyo et al. 2001).
30. ***Volvariella***: There are about 12 edible species across 27 countries (Boa 2004). The most common species is *V. volvacea;* it was first cultivated by Buddhist monks for their consumption. Later, in 1875, it was gifted to the royal family as a tribute. Cultivation of these paddy straw mushrooms was first started almost 300 years ago during the eighteenth century (Chang 1977). It was introduced to other parts of the Asian counties during 1932 to 1935 (Baker 1934; Chang 1974) (Reshetnikov et al. 2001). Following are some countries that are either harvesting from the wild or cultivation: Benin, Central Africa, Chile, China, Congo, Costa Rica, Hong Kong, Indonesia, Ghana, India, Israel, Madagascar,

Malawi, Mauritius, Mexico, Nepal, Nigeria, Peru, Russia, Taiwan, Thailand. Some common edible species are: *V. bombycina, V. bakeri, V. diplasia, V. esculenta, V. earlei, V. parvispora, V. speciosa, V. terastria* and *V. volvacea* (Bouriquet 1970; Oso 1975; Vasilèva 1978; Sarkar et al. 1988; Remotti and Colan 1990; Wasser 1995; FAO 1998; Adhikari 1999).

2.4 Nutrional Properties of Edible Mushrooms

With a long history of mushrooms, as food source, they are also reported for favorable nutritional effects on human health. The ancient Romans called "food of the gods" and the first Egyptians called the "gifts from God of Osiris" and Chinese called it "the elixir of life". Chang (1999) stated that over 2000 years mushrooms were consumed for their nutrition and therapeutics properties in China. In vegetarian diets, these nutrients are extremely valuable because they offer all the essential amino acids; they have higher protein content than most vegetables. Among the 2000 edible mushrooms, ca. 850 spp. are available in India. The edible mushrooms have wider range of usage not only as food but also in pharmaceuticals, nutraceuticals and cosmeceuticals. They are in rich carbohydrate, high proteins content (including amino acids), fibre, low fat and calories, and chitin. In addition, trace elements such as calcium, phosphorus, iron, copper, chlorine, sodium, zinc, manganese and bromine are present; it can be recommended for those who have high cholesterol because mushroom has very low fat content (Mattila et al. 2001; Barros et al. 2007). They also possess higher quantities of vit A, B complex (vit B1 (Thiamin), B2 (Rhiboflavin), B3 (pantetonic acid), B5 (Nicotinic acid) that are reported to be good for the nervous system. Besides, their vit C and vit D concentration is 5-10 times higher than vit B3. Mushrooms also possess various metabolites, such as phenolics, flavonoids, polyketides, carotenoids, terpenoids, variegatic acid, quinones and steroids (Teissedre and Landrault 2000; Cheung et al. 2003). Presence of phenolics and flavonoids plays a vital role in antioxidant property of mushrooms since they authorize to be reducing agents and also as singlet oxygen quenchers, respectively (Rice-Evans et al. 1996). Nutritional composition of common edible mushrooms were listed Table 2.1. The nutrient constituents of mushrooms such as protein, amino acids, dietery fiber, carbohydrates, lipids, micro-nutrients, minerals, ash and less fat and nearly no cholesterol are accountable for the medicinal properties (Tsai et al. 2007; Chang and Wasser 2012; Liu et al. 2012; Kalogeropoulos et al. 2013).

2.4.1 Protein

The dietary significance of mushrooms is mainly associated to the protein index. Mushroom is known to posses more dietary protein value when compared to protein from plant origin (FAO 1991). Varying protein constituent of mushrooms is

Table 2.1 Nutritional compositions of important wild edible and cultivated mushrooms

Species	Common names	Carbohydrate	Crude fat	Crude fiber	Crude protein	Ash	Reference
Agaricus bisporus	Button mushroom	74	2.18	-	14.08	9.74	Reis et al. 2012
Agaricus brasiliensis	Almond mushroom	26.74	2.62	-	26.74	6.81	Tsai et al. 2008
Agaricus campestris[b]	Meadow mushroom	58.16	0.11	-	18.57	23.16	Pereira et al. 2012
Amanita caesaria	Caesar's mushroom	55.63 ± 0.06	3.50 ± 0.00	-	34.77 ± 0.06	6.05 ± 0.01	Ouzouni et al. 2009
Armillaria mellea[a]	Honey fungus	65.47 ± 0.15	2.10 ± 0.02	-	24.47 ± 0.12	7.95 ± 0.02	Ouzouni et al. 2009
Armillaria tabesceus[a]	Ringless honey mushroom	66.87 ± 0.06	2.54 ± 0.03	-	22.90 ± 0.20	7.63 ± 0.15	Ouzouni et al. 2009
Boletus aereus[a]	Queen bolete	62.10 ± 0.10	4.47 ± 0.02	-	27.17 ± 0.15	6.25 ± 0.02	Ouzouni et al. 2009
B. armeniacus	-	68.1	1.56	-	18.25	12.09	Pereira et al. 2012
B. edulis	Black headed bolete	70.95	2.45	-	21.07	5.53	Heleno et al. 2011
B. erythropus[b]	Red stemmed bolete	52.43	0.75	-	20.92	25.90	Grangeia et al. 2011
B. reticulates[b]	-	55.16	2.55	-	22.57	19.72	Heleno et al. 2011
Calocybe gambosa	St.George mushroom	69.82	0.83	-	15.46	13.89	Vaz et al. 2011
Calvatia utriformis[b]	Saddle shaped buff ball	59.92	1.92	-	20.37	17.81	Grangeia et al. 2011
Cantharellus cibarius[a]	Chanterelle, Yellow Chanterelle, Girrole	66.07 ± 0.23	2.88 ± 0.02	-	21.57 ± 0.21	9.44 ± 0.01	Ouzouni et al. 2009
Clitocybe odora[b]	Aniseed mushroom	70.66	2.46	-	17.33	6.42	Akata et al. 2012
C. subconnexa[a]	-	27.35 ± 0.13	1.02 ± 0.09	38.74 ± 0.79	7.42 ± 0.25	5.98 ± 0.04	Heleno et al. 2015
Coprinus comatus	Shaggy ink cap	70.35	1.13	-	15.67	12.85	Vaz et al. 2011
Fistulina hepatica[a]	Beefsteak fungus, Ox tongue	66.00 ± 0.10	3.17 ± 0.02	-	22.60 ± 0.20	8.20 ± 0.10	Ouzouni et al. 2009
Flammulina velutipes[b]	Velvet Shank	70.85	1.84	-	17.89	9.42	Pereira et al. 2012
Flammulina velutipes	Velvet Shank	85.99	2.9	-	3.87	7.3	Reis et al. 2012
Hygrophorus russula[a]	Russula Wax- cap	53.33 ± 0.06	6.00 ± 0.10	-	32.47 ± 0.06	8.18 ± 0.02	Ouzouni et al. 2009
Hypsizigus marmoreus	White beech mushroom	68.56	4.9	-	19.6	7.75	Lee et al. 2009
Laccaria laccata[#]	Deceiver	12.77	3.76	-	62.78	20.69	Heleno et al. 2009
Lactarius deliciosus[b]	Saffron milk cap	64.63	8.02	-	20.02	7.15	Akata et al. 2012
Lentinula edodes	Shiitake mushroom	87.14	4.4	-	1.73	4.4	Reis et al. 2012
Lepista nuda[a]	Wood Blewit	56.33 ± 0.15	3.23 ± 0.01	-	34.37 ± 0.15	6.03 ± 0.02	Ouzouni et al. 2009

Lycoperdon echinatum[#]	Spiny puff ball	65.83	1.22	-	23.52	9.43	Grangeia et al. 2011
Macrolepiota dolichaula	Paraol Mushroom	56.2 ± 0.10	3.2 ± 0.20	4.85 ± 0.18	19.95 ± 1.35	7.3 ± 0.15	Atri et al. 2014
M. procera	parasol mushroom	60.82 ± 0.11	3.4 ± 0.08	5.1 ± 0.22	19.95 ± 1.06	1.93 ± 0.06	Atri et al. 2014
Pleurotus eryngii	king trumpet mushroom, French horn mushroom or king oyster mushroom	81.37	1.45	-	11.0	6.18	Reis et al. 2012
P. ostreatus	tree oyster mushroom or the grey oyster mushroom	85.86	1.4	-	7.02	5.7	Reis et al. 2012
P. sajor-caju	Oyster *Mushroom.*	55.3	1.0	-	37.4	6.3	Akyüz and Kirbağ 2010
Ramaria largentii[a]	Orange coral mushroom	87 ± 0.25 6.	67 ± 0.12 58.	-	80 ± 0.46 5.	67 ± 0.12	Ouzouni et al. 2009
Russula cyanoxantha[b]	Chacoal buner	74.65	1.52	-	16.8	7.03	Grangeia et al. 2011
R. delica	milk-white brittlegill	63.87 ± 0.31	4.44 ± 0.04	-	26.10 ± 0.30	5.61 ± 0.03	Ouzouni et al. 2009
Termitomyces badius	Bhatolian+, Baat Koir+	39.0 ± 0.17	2.2 ± 0.10	2.5 ± 0.01	44.00 ± 0.10	6.6 ± 0.03	Atri et al. 2014
T. heimii	Goal Tatmour[c], Joru Koir[c]	36.2 ± 0.72	1.65 ± 0.19	5.0 ± 0.11	40.95 ± 0.84	8.6 ± 0.05	Atri et al. 2014
T. mammiformis	Goal Tatmour[c], Joru Koir[c]	47.65 ± 0.02	3.3 ± 0.17	8.0 ± 0.26	23.45 ± 0.04	9.9 ± 0.09	Atri et al. 2014
T. striatus	Goal Tatmour[c], Joru Koir[c]	60.27 ± 0.20	3.25 ± 0.06	4.1 ± 0.15	12.95 ± 0.05	12.13 ± 0.33	Atri et al. 2014
Volvopluteus gloiocephalus[a]	Big sheath mushroom	13.97 ± 0.34	4.62 ± 0.04	39.12 ± 0.29	19.66 ± 0.14	14.19 ± 0.07	Heleno et al. 2015

[a]g/100g of tissue
[b]Wild edible mushoom
[c]Local names

reliant on both physical and biological causes and it also differs during the fruiting body development and on **genetic structure** of the species (Ragunathan and Swaminathan 2003; Agrahar and Subbulakshmi 2005; Chang et al. 1981). For example, the total protein content of mushrooms is considerably low when boiled but remained relatively constant when air-dried at 40°C (Barros et al. 2007). Xu et al. (2011) published a comprehensive data of bioactive proteins from mushrooms. Mushrooms may not be having protein more than that of animal meats but the amount of crude protein is above than the other foods (Chang and Miles 1993). In cultivated mushrooms such as *A. bisporus*, *L. edodes*, *Pleurotus* spp., and *V. volvacea,* the total protein index ranges from 1.75 to 3.63% (Chang 1980). The cultivated mushrooms like *A. bisporus, P. ostreatus* and *P. sajor-caju* possess higher protein content than the untamed mushroom (Akyüz and Kirbağ 2010). In *P. ostreatus*, highest protein content with 92% digestibility was reported (Vetter and Rimoczi 1993).

Litchfteld et al. (1963) analyzed protein index in the dried mycelium in *Morchella* spp. The commercial morel mushroom powder found to have considerably higher protein content (51 g/100g dm) than the other three cultivated species viz., *M. crassipes* (22.8 g/100g dm), *M. esculenta* (25 g/100g dm) and *M. hortensis* (26.9 g/100g dm), (51 g/100g dm). The total protein in dried mycelium of *Agaricus arvensis* (28.16%), *A. campestris* (30.16%), *Morchella deliciosa* (29.16%) and *M. esculenta* (34.7%) was reported by Samajipati (1978).

The crude proteins of *C. indica*, *L. subnudus* and *V. volvacea* were found to be 14 to 27% (Purkayastha and Chandra 1976). Haddad and Hayes (1978) determined the protein content from the mycelium of *A. bisporus* (32 to 42% dm) but the total protein content of dried *A. bisporus* was found to be 46.5% dry weight basis, which is slightly higher when compared with mycelia protein content (Abou et al. 1987). The protein content in *Lactarius deliciosus* and *L. sanguifluus* was 14.71 to 17.37% and 15.20 to 18.87%, respectively (Sharma et al. 1988).

Bauer-Petrovska (2001), studied the protein profile of 52 different Macedonian edible mushrooms belongs to 17 different genera. His investigation revealed the maximum protein content was 48.81–52.06% dm in *Tricholoma georgii*, *Macrolepiota mastoidea*, and *Calvatia caelata,* while *Laetiporus sulphureus* and *Cantharellus cibarius* contains low protein content (14.00–16.19% dm). Maximum amount of albumins and globulins was observed in WEF but prolamins and glutelins are present extremely less quantity (Bauer-Petrovska 2001). Numerous researchers revealed that truffles acquired more protein than the other edible mushrooms (Singer 1961). Desert truffles composed of 20–27% (dm) protein (Kagan-Zur and Roth-Bejerano 2008). Three truffles collected from Iraqi namely, *Terfezia claveryi*, *Tirmania nivea* and *T. pinoyi* posses 8.02 to 13.84% protein content (Hussan and Al-Ruqaie 1999). Total protein content of Saudi Arabian black (Gibaah and Kholeissi) and white (Zubaidi) desert truffles ranged from 19.59 to 27.18% (Sawaya et al. 1985). So mushroom is a promising food that possibly helps to overcome the malnutrition crisis in the world.

2.4.2 Essential Amino Acids

Based on essentiality it is classified as essential amino acids (cannot be made by the body, supplemented to diet) and non-essential amino acids (can be synthesized by our body) (Young 1994). The proteins from commercially cultured mushrooms possess amino acids necessary for us and lysine is the important one among them, whereas tryptophane and methionine are the least required essential amino acids (Hughes et al. 1958; Altamura et al. 1967). The amino acid composition in some mushroom varieties can be equivalent to that of hen's egg and several species of mushroom is nearly equal to or superior than soy proteins (Yin and Zhou 2008). Hence, addition of mushrooms in vegan diet aid to achieve the essential amino acids, where intake of animal based protein is restricted (Galante and de Araujo 2014). Available literature suggests that the amino acid constituents of mushroom protein were meagerly studied even though they posses more nutrients than plants (Kalač 2009). The unique umami savour of mushrooms is due to the presence of aspartic and glutamic acid (Phat et al. 2016). Five different wild edible *Lentinus* spp. were rich in aspartic acid; maximum amount is present in *L. squarrosulus* (0.25 - 0.37%) (Sharma et al. 2012). Sawaya et al. (1985) were the first to report sulphur amino acids such as cystine, lysine, methionine and tryptophan in *Terfezia claveryi*, *Tirmania nivea* and *T. pinoyi*. Later they have observed sulphur rich amino acids in European truffles. These amino acids also limit the assimilation of mushroom protein (Dabbour and Takruri 2002). According to Bano and Rajarathnam (1982) *Pleurotus* spp. contains the lowest essential amino acids (tryptophane and methionine).

Many mushroom lectins have been discovered in past few years. The first known fungal lectin was from fly agaric mushroom (*Amanita muscaria*). The lectin activity reported to be related with the toxicity of the fungi (Ford 1910). Soon lectins from many common edible mushrooms including *B. edulis*, *L. deliciosus* and *L. edodes* reported to posses autonomy toxicity (Guillot et al. 1991; Tsivileva et al. 2005; Vetchinkina et al. 2008). Few mushroom lectins known to tolerate extensive variation in pH and temperature. Lectin derived from *V. volvacea* was found to be stable even at 80 °C and wide range of pH (Lin and Chou 1984). Lyophilized powder of *A. bisporus* lectin is commercialized and marketed by Sigma Aldrich Co.,

The exogenous amino acid content of frozen *P. ostreatus* (798 mg/100g of fm) is high when compared with *A. bisporus* (651 mg/100g fm) (Bernaś and Jaworska 2010). The amino acid of canned *A. bisporus* was higher (913.6 mg/100 g fm) than the *P. ostreatus* (769.3 mg/100g fm) (Jaworska and Bernaś 2011).

2.4.3 Fats/ Lipids

Crude fat (total lipids) of mushrooms constitute wide range of lipid complexes with free fatty acids, sterols, sterol esters, glycerides (mono-, di-, and tri) and phospholipids. According to Crisan and Sands (1978), the crude fat in mushroom ranges

between 1% to 20% dm. Chang and Miles (2004) reported total lipids, occurrence of unsaturated fatty acids and abundance of linoleic acid from several mushroom species such *Agaricus, Auricularia, Boletus, Flammulina, Lentinula, Pleurotus* and *Volvariella* which vary from 1.1 to 8.3% dm. The total lipid of cultivated and wild strains of *P. ostreatus* was 3-5% (Hiroi 1982). The cap region contains more lipids when compared with the stalk. Total fatty acids in wild and cultivated strains of *P. ostreatus* constitute 20-30% neutral lipid, about 10% of glycolipid, 60-70% of phospholipid and 70-80% of linoleic acid. About 10 saturated, 6 monoenic and 4 polyunsaturated fatty acids were identified in *Boletus* spp.; linoleic, oleic and palmitic acids were primary that constitutes about 86–94% of total fatty acids (Hanuš et al. 2008). Phosphatidyl ethanolamine and phosphatidyl choline to be the most important individual phospholipids present in *A. bisporus* (Holtz and Schisler 1971) but few strains lack these fatty acids. Of the 58 edible mushroom screened, phosphatidylcholine was the major phospholipid found in 55 edible species (Vaskovsky et al. 1998). Huang et al., (1985) study shows the unusual elevated level of ergosterol and provitamin D2 interfered saponifiable lipid production in *V. volvacea.* Occurrence of high content of unsaturated fatty acids made WEF as nutritional dietary supplement and food.

2.4.4 Fiber and Carbohydrates

Fiber Still many WEF are underutilized and less explored in the view as a source of dietary fibre. A cluster of indigestible carbohydrates is crude fibre in other words **carbohydrate polymers** with ten or more monomeric units are called as dietary fibre, which cannot be hydrolyzed by the endogenous enzymes in humans (Codex 2010). *Boletus* spp. contains higher quantity of insoluble fibre (22-30% dm) than soluble (4–9% dm) (Manzi et al. 2004). In general, mushrooms reported to have 40% dm of crude fibre except *Craterellus aureus* and *Sarcodon aspratus* (5% dm). In *Pleurotus* spp. fibre content ranges from 7.4 to 27.6% dm but comparatively less in *V. volvacea* (4 to 20% dm) (Li and Chang 1982).

Carbohydrates In general, mushrooms constitute less amount of carbohydrate. It is an ideal diet for diabetic people, since its showing extremely slight consequence on human blood glucose level. They are having unique carbohydrates that can be stored as glycogen, which is common in human and animals but not as starch as in case of plants (Kalač 2013). Mushroom carbohydrates may comprise of hexoses, methylpentoses, pentoses, amino sugars, disaccharides, sugar acids and sugar alcohols (Crisan and Sands 1978). Mushroom polysaccharides are also best known for its **antitumor** and **immunomodulating** properties. These properties are reported to be possessed by many higher basidiomycetes because of the presence of some specific carbohydrates including, arabinose, fructose, fucose, glucose, maltose, mannitol, mannose, rhamnose, sucrose, trehalose and xylose (Zaidman et al. 2005; Zhang et al. 2007).

Structurally polysaccharide is composed of a backbone of β (1, 3)-linked glucose residues with acidic sugars, galactose and mannose residues in branches (Yoshioka et al. 1975). β-glucans are the important cell wall component of fungi which is the key polysaccharides found in mushrooms. They act as ligand and activate the membrane receptors to induce signaling pathways including defence against pathogenic microbes (Falch et al. 2000; Ishibashi et al. 2001; Kataoka 2002). They also stimulate the human immune system from detrimental contaminants and mutagens and provoke adaptive and innate resistant together (Vetvicka 2004). β-glucans of both wild and cultivated mushrooms are accountable for the anticancer, anticholesterolemic, antioxidant, immunomodulating and neuroprotective activities. *Pleurotus* spp. contains higher carbohydrates i.e. 46.6 to 81.8% when compared to *A. bisporus* (60% dm) (Bano and Rajarathnam 1982).

About 80–90% dm of mushroom cells consists of chitin. Eight *Boletus* spp. were reported to have 6.8–10.2% (dm) of carbohydrate (Manzi et al. 2004). When compared with water soluble polysaccharides, it known to have less bioactivities. **Chitin** is indigestible for humans and act as an important dietary fibre (Tao et al. 2006). Due to the presence α and β-glucans, chitin, galactans, hemicellulose, mannans and xylans mushrooms are known to be a prospective candidate for a potential source of **prebiotics**.

Mannitol is responsible for mass of texture of mushroom. Kalač (2012) analyzed the free sugar content in 27 species of WEF belong to 19 different genera. He observed the average amount of mannitol and trehalose ranges from 28.9 to 39.2 g kg^{-1} dm whereas glucose, fructose, mannose, ribose, sucrose and xylose occur at a low level. Trehalose and mannitol were reported at higher level in cultivated and mycorrhizal edible mushrooms (Reis et al. 2011) but these are not easy for humans to digest. During the course of processing there is slight decrease in the quantity of mannitol and trehalose (Barros et al. 2007). Grangeia et al., (2011) investigation revealed that the content of sugar in edible mycorrhizal species is higher (160 to 420 g kg^{-1} dm) than the edible saprotrophic mushrooms (up to 150 g kg^{-1} dm).

2.4.5 Mineral Composition

Mushrooms are also source minerals, possess highest amount of potassium (K), subsequently calcium (Ca), magnesium (Mg), phosphorus (P) and sodium (Na). These are known as major and minor mineral elements constitutes cadmium (Cd), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn) etc (Bano and Rajarathnam 1982; Li and Chang 1982). The Cu content is higher in *Pleurotus* spp. and varies from 12.2 to 21.9 ppm (Bano and Rajarathnaum 1982). Singer (1961) reported important minerals including Al, Ca, Cu, Fe, K, Mg, Mn, Na, P, S, Si and Zn from truffles. The European truffles contain abundant potassium, phosphorus, iron, and calcium (Saltarelli et al. 2008).

Mushrooms studied from metropolitan and industrial areas are contaminated with lethal compounds such as As, Cd, Hg, and Pb (Falandysz and Borovička 2013). The content of Cd, Cr, Ni and Zn from the mushrooms collected in rural areas is

comparatively high, which may be because of quarries and industrial activities (Zhang et al. 2015). Silver (Ag) is one of the metallic elements with no dietary importance; due to its high affinity for proteins it is toxic and consequently gets collected in mushrooms (Falandysz and Borovička 2013).

Ash: The amount of ash in edible mushrooms is the poorly studied factor or this is not measured as a component for the estimation to analyze the mushroom quality (Falandysz et al. 2007; Falandysz et al. 2008). Estimation of ash requires high sophisticated laboratory infrastructure and instruments that may not be feasible for all (Falandysz et al. 2001). But the ash profile will give only general indication of mineral constituents of the mushrooms. The total ash content of mushroom is very less, only about 5–12% of dry matter.

2.4.6 Vitamins

Mushrooms composed of a number of primary vitamins including **vit B** complex, **vit C** and **vit D** (Cheung 2010; Kalač 2013). Information about vitamin composition of WEF has been lacking when compared with cultivated species (Mattila et al. 2001). The most potent provitamin A, β-carotene, is very low, $\geq$ 6 mg per kg dm found in Portuguese WEF (Pereira et al. 2012). The primary vitamins of mushroom constitute ascorbic acid, niacin, thiamine, tocopherols and riboflavin (Quan et al. 2007; Zhu et al. 2007; Yin and Zhou 2008; Zhou and Yin 2008; Xu et al., 2012). *Boletus edulis*, *B. speciosus* and *Thelephora ganhajun* were reported to possess tocopherol and vit D2 at a range of 8.9–45 and 4.7–194 mg/100g dm, respectively (Wu et al. 2005; Zhou and Yin 2008). In *Agaricus* spp. ascorbic acid content are relatively lower, unlike *B. edulis* and *C. cibarius*, which have higher content of ascorbic acid. Vit B complex have been reported from *A. bisporus* (white and brown), *L. edodes* and *P. ostreatus* (Caglarirmak 2011). Jaworska and Bernas (2009) stated that the levels of niacin and riboflavin decreased during mushroom processing. A type of vit B9 (total folates) have been quantified from several cultivated mushroom such as; crimini, chanterelle, enoki, maitake, morel, oyster, portabella, shiitake, UV-treated Portabella and white button mushrooms (Phillips et al. 2011). Tang et al. (2012) described ergosterol (640–1770 mg kg^{-1} dm) and also several phytosterols, especially brassicasterol from several *Tuber* spp. The amount of vitamins was found to have definite effects on the cooking and industrial processing of mushroom. In canned *Boletus*, vit B1 lost at a rate of 21–57% and vit B2 at a rate of 8–74% and at the worst case, reaching up to 76–99% lost in vit B complex (Yin and Zhou 2008; Zhou and Yin 2008).

2.4.7 Other Aromatic Metabolites

Each mushroom species posses a very characteristic aroma, which helps to determine them distinctly from other mushrooms (Cronin and Wada 1971). This unique characteristic aroma of mushrooms can be differentiated into volatile and

nonvolatile components (Maga 1981). Some of the C8 aliphatic components are responsible for the unique flavour of mushroom are; 1-octen-3-ol, 2-octen-1ol, 3-octanol, 1-octanol, 1-octen-3-one and 3-octanone (Cho et al. 2006). While, 1-octene and 2-octene (often 3-octanone) are responsible for the typical aroma in mushrooms (Combet et al. 2006).

Truffles are popularly known for its unique aroma. The distinctive feature of the truffles is they do not share same desirable aroma even if morphology is same. More than 200 VOCs have been reported from truffles (Kanchiswamy et al. 2015). Various VOCs were reported in six different species namely *Tuber aestivum, T. borchii, T. brumale, T. dryophilum, T. magnatum* and *T. mesentericum* in various ratios (Federico et al. 2015). Thiophene, sulfur containing volatiles is the characteristic of *Tuber borchii* (Splivallo and Ebeler 2015). Accordingly, aroma of truffles may vary from cheesey, creamy, dusty, earthy, gasoline-like, garlicky, leathery, pungent and vanilla-like (Xiao et al. 2015). Bis (methylthio) methane, Dimethyl sulphide, 3-Ethyl-5-methylphenol, Hexadecanoic acid, 5-Methyl-2-propylphenol and B-Phenylethanol are example of few aromatic compounds reported from truffle (Omer et al. 1994; Buzzini et al. 2005; Cullere et al. 2009). Various preservation methods including refrigeration (4 °C) (Saltarelli et al. 2008), irradiation (Nazzaro et al. 2007) and modified atmosphere packing (MAP) (Rivera et al. 2010) are employed for industrial preservations of these aroma compounds. Pinho et al. (2008) studied the volatile components of eleven WEF (*Amanita rubescens, Boletus edulis, Cantharellus cibarius, Fistulina hepatica, Hygrophorus agathosmus, Russula cyanoxantha, Suillus bellini, Suillus granulatus, Suillus luteus, Tricholoma equestre* and *Tricholomopsis rutilans*) and concluded with 65 such compounds are responsible for the odor of mushroom which could be a key character in identifying these mushroom.

2.5 Hallucinogenic Mushrooms

Hallucinogenic or magic mushrooms have been widely consumed by indigenous groups in Mexicans. It came into the public attention in 1957 and then gained more popularity since then. Comprehensive detail of magic mushrooms consumption and its role in rituals among Mexican tribes and others across the world gave a spark among the psychoactive mushrooms consumers (Wasson et al. 1978). The first record of hallucinogenic mushroom was credited to the Yoruba tribe of Nigeria in Africa. It was traced back to the Paleolithic period (7000 – 9000 years ago). Of the 180 type magic mushrooms in the world, *Psilocybe* spp. is the "true" magic mushrooms, generally called as “shrooms”. They possess psychoactive indole of tryptamines called psilocybin and psilocin that has low level of physiological toxicity and never give addiction except low to acute psychedelic effects (Johnson et al. 2008; Tylš et al. 2014). More than 3000 years, the **psychoactive** fungus belongs to the genera *Psilocybe* and perhaps *Panaeolus* have been used conventionally. Besides the shrooms, there are many mushrooms such as *Conocybe*, *Copelandia, Galerina, Gymnopilus*, *Inocybe*, *Lycodperdon*, *Mycena, Panaeolus*, *Panaeolina, Pholotina* and *Pluteus* etc., are known to posses tryptamine derivates. The use of magic mushrooms alone or with alcohol

Fig. 2.3 *Ancient origin of magic mushrooms Credit:* Robert Brusco

was comparatively safe (van Amsterdam et al. 2011) but with mild to adverse effects like psychological distress, dangerous behaviour and enduring psychological problems (Carbonaro et al. 2016). *Psilocybe* spp. can be easily mistaken in wild with morphologically similar and non- *Psilocybe* or inedible or poisonous mushrooms. But at times illegal selling of "*Psilocybe* like poisonous mushrooms" has become lethal to an individual leading to death. In many countries including Australia, America and Europe illicit growing, possession and sale of magic mushrooms is punishable. *Psilocybe* have been cultivated sacredly because of the special kind of neurotropic (hallucinogenic) chemical constituent Psilocybin. These mushrooms are recognized as little saints or flesh of the gods among the native religious people (Fig. 2.3). French mycologist Heim (1969) documented this neurotropic species as *Psilocybe* species, which has been traditionally used during spiritual practices (Guzman 2008). This provides evidence that ancient Egyptians were not an exclusive group to exploit this substance in rituals (Guzman 2008).

While in India, people are well aware of these mushrooms either consume it with omelette or along with bread/ butter jam or with bread/banana or with honey (personnel survey; unpublished data). Even though it is under punishable act, many law enforcement officials are least aware of it. So there is a dire need to have a study on systematic research and on the abuse of the same among the youth. Scientists have adapted simple screening techniques to discriminate psilocybin and non-psilocybin mushrooms (Marumaya et al. 2006). DNA-based approach and **LC/MS** has been adapted to detect hallucinogenic mushroom and psychedelic drugs, respectively in grow kits from illegal market (Gambaro et al. 2015).

Nevertheless, psilocybins have been prescribed by the physicians in treating neurotic disorders in humans. These studies are looking at psilocybin and other hallucinogens to treat a number of psychiatric and stress disorders including chronic depression, post-traumatic stress disorder, and drug or alcohol dependency.

However, the mechanism and pharmacological profile of pure drug has to be compared with mushroom preparations. Studies reveal that psilocybin may decrease the depression and death anxiety along with increased the positive attitude in life of cancer patients. Pure psilocybin, "Sandbox" was marketed by Novartis has been recommended by physicians for psychedelic psychotherapy. Potentials of psilocybin in curing obsessive compulsive disorder (Wilcox 2014) and cluster headaches (Sewell et al. 2006) have also been investigated.

2.6 Cutivation of Edible Mushroom

The cultivation practice of WEF started several centuries ago; *Auricularia auricula* was probably the first mushroom to be purposely cultivated around A.D. 600, followed by *Flammulina velutipes* (ca. 800 AD). According to the "*Chinese Book of Agriculture*" (1313), the first historical record on cultivated mushroom was *Lentinula edodes* (Chang and Hayes 1978). Later, in France (1600 AD) *Agaricus bisporus* were first cultivated in outdoor later followed by *V. volvacea* (1700 AD) and *Tremella fuciformis* (1800 AD). This shows that, earlier practice of mushroom cultivation included only of outdoor that implies the limited knowledge and understanding of developing spawn, substrate and composts. It was only at the later part of the seventeenth century, the spawning technique for *Agaricus* was developed (Treshaw 1944). Elliott (1985) described the method to achieve pure culture. Later this was successfully accomplished in United Kingdom, followed by France in 1894 and United States in 1902 (Chang and Miles 2004). Since then the progress in mushroom cultivation technique has improved by miles, cultivating over 100 of species and producing millions of tons worldwide (Chang and Mao 1995; Stamets 2000; Boa 2004) (Table 2.2).

Table 2.2 A global overview of wild edible mushroom production with respect to countries according to Food and Agriculture Organization (FAO), United Nations.

Sl. No.	Countries	Production in tonnes (2000)	Production in tonnes (2005)	Production in tonnes (2010)	Production in tonnes (2015	Production in tonnes (2016)
1	Albania	100	100	100	100	100
2	Algeria	113	170	211	2526	1890
3	Armenia	0	0	80	278	361
4	Australia	36000	47992	41295	42777	50387
5	Austria	1000	900	1300	1200	1400
6	Azerbaijan	0	0	1900	1515	1562
7	Belarus	5000	6851	7000	7568	10135
8	Belgium	46300	41420	39154	30440	29450
9	Bosnia and Herzegovina	1200	2000	1200	1228	1203
10	Brunei Darussalam	8	9	12	13	14
11	Bulgaria	11500	1427	1619	2520	1473

(continued)

Table 2.2 (continued)

Sl. No.	Countries	Production in tonnes (2000)	Production in tonnes (2005)	Production in tonnes (2010)	Production in tonnes (2015	Production in tonnes (2016)
12	Canada	80241	80071	78452	118642	133935
13	China, Hong Kong SAR	31	31	35	31	31
14	China, mainland	2400000	3400000	4826000	826152	7786368
15	Taiwan	8196	9643	7689	9939	11530
16	Cyprus	1730	1014	790	711	761
17	Czechia	1000	350	526	551	561
18	North Korea	5745	6030	5906	5927	5868
19	Denmark	8686	10946	3000	3930	3930
20	Estonia	0	0	0	130	51
21	Finland	1536	1996	1645	1248	1345
22	France	203861	138541	119373	101135	101949
23	Germany	62000	50000	60000	62594	72141
24	Greece	845	2292	1397	4400	3601
25	Hungary	16926	19734	14026	28621	32311
26	Iceland	447	438	579	550	585
27	India	24000	40000	40600	33699	29992
28	Indonesia	28000	30854	61376	33485	40906
29	Iran (Islamic Republic of)	0	0	74500	132331	150063
30	Ireland	59800	62400	54500	72200	70000
31	Israel	7500	9500	9500	11000	11000
32	Italy	72492	88361	684401	594835	683620
33	Japan	67224	66000	65764	65711	65579
34	Jordan	500	688	764	841	856
35	Kazakhstan	500	503	507	515	513
36	Kyrgyzstan	264	200	200	231	226
37	Latvia	500	530	135	64	62
38	Lithuania	6000	4087	10434	13824	15785
39	Luxembourg	16	5	5	5	5
40	Madagascar	1000	1487	1882	2269	2262
41	Malta	898	989	1088	2021	1676
42	Mongolia	0	200	253	310	326
43	Montenegro	0	0	600	600	600
44	Morocco	1800	1924	1996	2087	2105
45	Netherlands	265000	245000	266000	310000	300000
46	New Zealand	8500	8600	5687	2110	1740
47	Philippines	568	508	526	556	580
48	Poland	109273	160000	230000	252944	260140
49	Portugal	1196	1377	1500	10754	12093
50	Republic of Korea	20659	28375	26250	26292	26158

(continued)

Table 2.2 (continued)

Sl. No.	Countries	Production in tonnes (2000)	Production in tonnes (2005)	Production in tonnes (2010)	Production in tonnes (2015	Production in tonnes (2016)
51	Republic of Moldova	2000	2000	2000	2034	2135
52	Romania	5000	5630	9973	10955	14519
53	Russian Federation	6000	5000	5373	8660	9682
54	Serbia	12000	12521	5000	5365	5403
55	Singapore	0	3	117	32	30
56	Slovakia	600	1100	2335	2000	2074
57	Slovenia	1269	1200	1131	1074	1063
58	South Africa	7278	8385	12217	18267	18803
59	Spain	63254	137764	133000	218795	197010
60	Switzerland	7148	7440	8465	7307	7089
61	Thailand	9500	9800	5746	1147	960
62	Macedonia (FYROM)	2000	3000	2900	2876	2866
63	Tunisia	99	116	136	150	153
64	Turkey	7000	17000	21559	39495	40272
65	Ukraine	3500	6000	11000	12480	14740
66	United Kingdom	89900	74000	69300	103197	99813
67	United States of America	383830	386984	359469	429562	419630
68	Uzbekistan	397	464	600	673	694
69	Viet Nam	20500	17702	19934	22854	23701
70	Zimbabwe	230	350	526	697	684
71	China	2408227	3409674	4833724	8036122	7797929
72	European Union	1030582	1051064	1706632	1830148	1906833
73	Least Developed Countries	1000	1487	1882	2269	2262
74	Land Locked Developing Countries	5391	6717	8966	9129	9367
75	Small Island Developing States	0	3	117	32	30
76	Low Income Food Deficit Countries	31636	48531	49715	43496	39726
77	Net Food Importing Developing Countries	3399	4415	5031	5657	5702

Mushroom production has increased gradually in the agricultural related industries ever since the end of World War II. Initially, *Agaricus* production was at greater rate and subsequently there was a greater raise in production of *Lentinula*, *Flammulina*, and *Pleurotus* (Chang and Buswell 2008). In twentieth century, the wide uses of industrialized cultivation techniques were applied for the mushroom productions. The development of mushroom farming skills has been principally responsible for the raise in mushroom production in recent years.

2.6.1 Major steps in Mushroom Cultivation

Cultivation of mushroom is relatively a primitive process however with modernization and since the recognition of its important health benefits and upliftment of economy, it has become an industrial venture in most nation producing hundreds and thousands of tonnes every year. Nonetheless, production in small scales industries plays a major role in smaller markets in developing nations. In either case, the concept of cultivation focuses on increasing the yield within a short stipulated time. This requires proper understanding on selection of high-yielding strains and media for spawn making, improved management of the mushroom beds, including pest and dieases management. Besides, continous supply of mushrooms to the consumers and marketing are also vital progression in the mushroom farming. Thus, there are a number of factors involved in mushroom production and a successful grower requires scientific knowledge, training and practice. Mushroom cultivation generally occur in the following six phases that follows (Buswell 1984; Nair 1991; Dawit 1998; Chang and Miles 2004): (1) selection of a mushroom species, (2) selection of a fruiting culture, (3) development of spawn, (4) preparation of compost, (5) spawn running, and (6) mushroom development.

Many strategies have to be adapted for successful production of WEF. Principally, selection of mushroom strains which have high demand and market value has to be studied. Maintenance cost, influence of other environmental factors on mushroom growth and accessibility of substrate for cultivation are the other factors. The cultures of edible ones are capable of producing fruiting bodies under suitable growing conditions. Strain improvement techniques like “mating with other isolates” is not necessary in case of heterothallic or a homothallic species since they can able to form fruit bodies. To avoid the spore density in the air of mushroom houses, sporeless strains of *Pleurotus* spp. have gained great commercial interest than non-sporeless strains. The latter may lead to respiratory tract problem and allergy to the mushroom workers. Quality of the mushroom spawn is mainly depends on quality and combination of the substrates and genetic constitution of the mushroom.

There is synthetic compost which is used for growing most of the mushroom; they are made up of agricultural and chemical materials but without animal manure. The mycelium grows at geate rate when larger quantity of spawn is used but it may also increase production cost. The requiment of temperature, humidity, pH and aeration varies at every stages of mushroom poduction. “Flushes” or appearance of

mushrooms is in periodical cycles and they can be picked at different stages of development in accordance to consumer preference or market value. Nevertheless, harvesting varies among the species; *V. volvacea* and *P. pulmonarius* equires only simple farming activity than *A. bisporus, F. velutipes*, and *H. marmoreus* which needs a high-technology industry.

Among the hundred species of cultivated fungi, commercial markets are still dominated by *A. bisporus*, *L. edodes* and *Pleurotus* spp. and this account for nearly three quarters of the cultivated mushrooms grown around the world (Chang 1999; Boa 2004). Whether it is large scale industrial or small scale, cultivation edible fungi is profitable as well as they are highly nutritional as seen in countries such as Africa, Brazil, China, Mexico (Pauli 1999; Mshigeni and Chang 2000; Martinez-Carrera et al. 2001). On the other hand, cultivation of some species of mushroom such as *L. edodes* may lead decline in forests trees. Qingyuan of China is known as "mushroom capital of the world", suffering extensive deforestation from wood exploited for mushroom cultivation (Pauli 1998).

The number of cultivated species is ever growing as the technology and practical advice are easily available (Stamets 2000). Aside from saprobic species, **ectomycorrhizal** species can also be cultivated, where the tree are inoculated with the inoculum species which is allowed to infect the roots and form ectomycorrhizae, after which this tree are carefully tented for the production of fruiting body. Cultivation of ectomycorrhizal species are not fully developed and are constantly being refined and improved, cultivation of truffle mushroom is an example (Hall et al. 2007).

Some of the cultivated species, cultivated worldwide are given below (Stamets 2000; Chang and Mao 1995):

Agaricus arvensis, A. augustus, A. bisporus, A. bitorquis, A. blazei, A. campestris, A. subrufescens, Amanita brunnescens, Auricularia auricula-judae, A. fuscosuccinea, A. polytricha, Coprinus comatus, Flammulina velutipes, Laetiporus sulphureus, Lentinula edodes, Lentinus strigosus, L. tigrinus, L. tuber-regium, Morchella angusticeps, M. esculenta, Pleurotus cornucopiae, P. cystidiosus, P. eryngii, P. euosmus, P. ostreatus, P. pulmonarius, P. rhodophyllus, Pluteus cervinus, Polyporus indigenus, P. saporema, Volvariella bombcyina and *V. volvacea.*

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