CHAPTER -2
LITERATURE REVIEW

Mushrooms are a widely distributed food resource on earth and have been consumed because of their nutritional value and medicinal properties for over 2000 years. For their enjoyable flavor and taste, human health was improved by mushrooms due to their nutrients, including digestible proteins, carbohydrates, fiber, vitamins, minerals, and antioxidants (Acharya *et al.,* 2017, Zhang *et al*., 2016). A wide variety of bioactive compounds from medicinal mushrooms, which are widely used in eastern Asia, have been studied extensively, and these compounds including polysaccharides, lectins, lactones, terpenoids, and alkaloids have been reviewed (Rahi *et al*., 2016; Toledo *et al*., 2016). Nagy *et al*., (2017) reviewed bioactive mushroom polysaccharide composition and their synthesis and function. Besides their pharmacological features, mushrooms are becoming more important in our diet due to their nutritional value, high protein and low fat/energy contents. The mushroom protein contains all the nine essential amino acids required by humans. In addition to their good protein content, mushrooms are a relatively good source of the other nutrients like phosphorus, iron and vitamins, including thiamine, riboflavin, ascorbic acid, ergosterol, and niacin. Mushrooms are the sources of bioactive substances such as secondary metabolites (organic acids, terpenoids, polyphenols, sesquiterpenes, alkaloids, lactones, sterols, metal chelating agents, nucleotide analogs and vitamins) glycoproteins and polysaccharides, mainly 1, 2-glucans. Due to the presence of biologically active compounds of medicinal value they are used as anticancer, antiviral, hepatoprotective, immunopotentiating and hypocholesterolemic agents. Present review is aimed to discuss the high nutritional and therapeutic potential of mushrooms and their applications as functional foods or as a source of nutraceuticals for maintenance and promotion of health and life quality

2.1. World scenario of Edible mushroom production

Among the numerous species of mushroom, Oyster Mushrooms are more advantages over other mushroom in terms of easy for cultivation, role in biodegradation and bio-remediation, extracellular enzymes production and neutraceuticals production (Rashad *et al*., 2009). *Pleurotus* species, commonly known as oyster mushrooms, are edible fungi cultivated worldwide especially in south East Asia, India, Europe and Africa (Mandeel *et al.,* 2005). Oyster mushrooms is the third largest (Obodai *et al.*, 2003) commercially produced mushroom in the world. Sanchez (2010) stated that *P. ostreatus* is the second largest cultivated cushroom species next to *A. bisporus* in the world market. Mushroom cultivation is the fifth largest agricultural sector in China (Zhang *et al.,* 2014). The expansions of mushroom cropping decline the price of mushrooms and hence it safe guard food insecurity (Zhang *et al.,* 2014). Although edible mushrooms represent an important agricultural product worldwide, only a few of them (*Agaricus*, *Lentinula*, *Pleurotus*, *Auricularia*, *Volvariella*, *Flammulina*, *Tremella* and a few others) can be cultivated. The most significant progress in mushroom cultivation occurred in France in the seventeenth century when *A. bisporus* was grown in a composted substrate (Chang *et al.,* 2004). The cultivation process of *A. bisporus* is complex but highly efficient with up to 9 crops per year at modern mushroom farms, resulting in an annual crop value of about $4.7 billion worldwide (Sonnenberg *et al.,* 2011). China, the United States and the Netherlands are the largest mushroom producers in the world and a large part of the produced mushrooms is exported. According to State Department of Agriculture/Horticulture, in India, in seventies and eighties button mushroom was grown as a seasonal crop in the hills, but with development of technologies increased understanding of the cropping systems, and mushroom production shot up from mere 5000 ton in 1990 to 1, 00,000 ton in 2006. The appropriate production based on the report is as given in Table1. In India the total production of mushroom is about 1,13, 315 tons (Wakchaure, 2013), of which 80 % share goes to button mushroom the 20% share goes to other tropical mushroom such as oyster, paddy straw mushroom, milky mushroom. In India, at present, four mushroom varieties such as *A. bisporus*, *Pleurotus sp*, *Volvariella spp.* and *C. indica* have been recommended for the year round cultivation. The Indian subcontinent is known worldwide for its varied agro climatic zones with a variety of habitats that favour rich mushroom biodiversity (Thakur *et al.,* 2006; Thakur *et al*., 2011).

Table1. Contribution of states in mushroom production in India

States	**Production (tons per year)**				
	Button	Oyster	Milky	Others	Total production
Andhra Pradesh	2,992	15	15	0	3,022
Arunachal Pradesh	20	5	0	1	26
Assam	20	100	5	0	125
Bihar	400	80	0	0	480
Chattishgarh	0	50	0	0	50
Goa	500	20	0	0	520
Gujrat	0	5	0	0	5
Haryana	7,175	0	3	0	7,178
Himachal Pradesh	5,864	110	17	2	5,993

J&K	565	15	0	0	580
Jharkhand	200	20	0	0	220
Karnataka	0	15	10	0	25
Kerala	0	500	300	0	800
Maharashtra	2,725	200	50	0	2,975
Madhya Pradesh	10	5	0	0	15
Manipur	0	10	0	10	60
Meghalaya	25	2	0	0	27
Mizoram	0	50	0	0	50
Nagaland	0	75	0	250	325
Orissa	36	810	0	5,000	5,846
Punjab	58,000	2,000	0	0	60,000
Rajasthan	100	10	0	10	120
Sikim	1	2	0	0	3
Tamil Nadu	4,000	2,000	500	0	6,500
Tripura	0	100	0	0	100
Uttarakhand	8,000	0	0	0	8,000
Uttar Pradesh	7,000	0	0	0	7,000
West Bengal	50	50	0	0	100
Union Teriitories					
Andaman-Nikobar Islands	0	100	0	0	100
Chandigarh	0	0	0	0	0
Dadar&Nagar Haveli	0	0	0	0	0
Daman & Diu	0	0	0	0	0
Delhi	3,000	50	20	0	3,070
Lakshadweep	0	0	0	0	0
Pondicerry	0	0	0	0	0

Source: Mushrooms Cultivation, Marketing and Consumption, Directorate of Mushroom Research (Indian Council of Agricultural Research) Chambaghat, Solan-173213 (HP)

2.2. Button mushroom cultivation

Agaricus bisporus (Lange) Imbach is the most wild and cultivated edible mushroom and presents more than 40% of world mushroom production followed by *Lentinula edodes, Pleurotus sp* and *Flammulina velutipes* (Mostafa, 2014; Sharma *et al*., 2016). The global production in 1990s was more than $ 800 million/year and increased to $ 12,250 in 2002 (Andersson *et al.,* 2004). *A. bisporus* has delicious taste, high nutritional value, high aroma or flavoring taste and is used as a food and in food industries (Mattila *et al.,* 2010). It has high biological activity, low toxicity and is used in folk classical medicines, flavouring of food products, perfume, cosmetics and pharmaceutical industries, as defoaming agents and to improve the shelf life and safety of minimally processed fruits (Dastager, 2009).

2.2.1. Compost preparation for cultivation of Button Mushroom

Composting is the biological decomposition and stabilization of organic substrates under condition which allow development of thermophilic fungi as a result of biologically produced heat, with a final product sufficiently stable for storage and application to land without adverse environmental effect. Composting is the process by which various aerobic micro-organisms decompose raw organic materials to obtain energy and matter they need for their growth and reproduction. Good composting comes about through a process involving microorganisms, organic matter, air, moisture, and time (Mitchell *et al*., 2015). In composting, micro and macro organisms such as bacteria, fungi, insects, worms, mites, protozoans, actinomycetes etc., in an aerobic reaction, convert the carbon from dead plants into energy for their own growth and in so doing release nutrients from the decaying plants into their body and later into the soil (Mitchell *et al*., 2015).

The composting process starts with the activities of macro organisms such as and beetles which break the bulk organic material into smaller particles. This increases the exposure and the surface area of the materials for microbial attack (Chen *et al.*, 2011). After the attack of macro-organisms, micro-organisms such as bacteria, fungi, actinomycets and protozoa colonize the organic material and initiate the composting process (Chen *et al.*, 2011). Since the oxygen remaining in the pile is quickly consumed by the resident microorganisms, the compost pile must be regularly aerated by turning to prevent anaerobic conditioning. The composting process is done by several microorganisms of specific temperature requirements; mesophilic microbes which function best at 24^{o} C to 47^{o}C initiate the composting process. Their activities raise the temperatures which cause their inactivation and therefore paving the way for thermophilic microorganisms which love to work in the high temperature such as 47 ^{o}C. Decomposition at this phase is very active until most of the nutrients are used up by the thermophiles. Decomposition then slows down andtherefore decreasing the temperature. Mesophiles then take over again and complete the decomposition process (Chen *et al.*, 2011).

Factors that affect the composting include nutritious food for the microbes, suitable moisture, pH, oxygen and temperature (Chen *et al.*, 2011). Micro-organisms need nutrients such as nitrogen, phosphorus, sulfur etc. to grow and to reproduce and these nutrients occur in the raw materials used in the compost mix and therefore additional fertilizer is often not needed (Mitchell *et al*., 2015). Good compost must have a balance of carbon-rich and nitrogen rich material. Too much carbon slows decomposition because nitrogen will be used up and some organisms may die, but other organisms may form new cell material using their stored nitrogen. Thus in the process more carbon is burned and therefore reducing the carbon content while nitrogen is recycled (Chisholm *et al.*, 2012). Generally a C: N ratio of 30:1 is ideal for microbial activity. Thus bean straw which has high content of nitrogen will serve as good compost. To ensure effective and active work of the microbes on the substrates so as to release the nutrients. Mitchell *et al*., (2015) suggested that the particle size of the materials can be reduced through grinding, chopping or cutting. Small particles have more surface area for microbial activity and are easier to break down for the release of the nutrients. Moisture is one of the important factors for composting. Microbes need water for their activity and therefore must be supplied. All materials in the pile must be moist, but not soaking wet (Mitchell *et al*., 2015). The mixed material should be moist but water should not be squeezed out of it when handled with the hand. For aerobic composting, the maximum moisture content should be kept at a level that allows the whole composting process to be aerobic (Chen *et al.,* 2011). The optimal water content of composting should be between 50 and 60% by weight. Too low water will slow down the activities of the microbes whilst too much water will lead to anaerobic conditions (Chen *et al.,* 2011). Since microbes work within a specific pH medium, there is the need to monitor the pH of the compost to ensure proper microbial activity. The optimal pH for the activities of the microbes ranges from 6.0 to 7.5 for bacteria and 5.5 to 8.0 for fungi (Chen *et al*, 2011). This means fungi have a wide range of pH for operation of which oyster mushroom is not an exception.

Oxygen is one of the most important factors for effective composting. This is because the microorganisms need oxygen for their growth and multiplication. As microbial activity in the compost increases, more oxygen is consumed and must therefore be replaced by regular turning (Chen *et al.,* 2011). Without sufficient oxygen, anaerobic process can set in and will produce undesirable odor. The pile needs to be porous to pull air into it from outside (Mitchell *et al*., 2015).To ensure air circulation within the pile, it is important to turn the pile regularly and it is also important to include a range of different sized and shaped materials. To turn the pile, the temperature of the pile should be checked first and a shovel is used to dig the middle of the pile to notice the appearance of a steam. The materials outside should then be turned in and the materials within should be turned outside. Temperature as the amount of heat dissipated by the body is also important for composting. Temperature affects microbial growth, microbial activity and hence the rate at which the raw materials decompose (Chen *et al.*, 2011). Higher temperatures favor faster breakdown of the organic materials. However extreme temperature can inhibit the activities of the microbes (Chen *et al.*, 2011). The pile must be turned after the correct temperature has been established. The area for the composting must be flat and free from stones, tree stumps, drainage lines and weeds. The materials can also be covered if there is excessive rainfall.

2.2.2. Role of Fungal diversity in composting

A variety of microorganisms bring about composting. One of the most important microorganisms is fungi. Fungi have the ability to degrade decay-resistant materials such as waxes, proteins, hemicelluloses, lignin and pectin (Chen *et al.*, 2011). During preparation of compost, microorganisms degrade about 40% of the dry matter of compost, the dry matter being of potential value for the nutrition of *A. bisporus*. Thermophilic microorganisms in compost have been studied extensively by Fermor *et al.*, (2010). It remained difficult to state the dominating species among actinomycetes, other bacteria, and fungi. Microbial diversity of compost is important because it takes part in breakdown of organic matter to humus matter. Mesophilic microflora from the pioneer community while thermophilic represents the climax community (Agrawal *et al.*, 2014). According to Rosenberg (1978) and Satyanarayana (1992) the typical pioneers for composting is *Rhizomucor spp*. and *Aspergillus fumigates* that have pH optima just below 7 and the temperature optimum about 40°C. When self-heating and ammonification start and the pH reach 9, the pioneers disappear. *Talaromyces thermophilus* and *Thermomyces lanuginosus* have relatively high pH and temperature optima. Their high thermal death points give a selective advantage in the period of maximum heat production. *Scytalidium thermophilum* and *Chaetomium thermophilum* grow fast and degrade cellulose strongly (Straatsma *et al.*, 1993). The density of *S. thermophilum* in compost was found to be positively correlated with mushroom yield (Agrawal *et al.*, 2014) and *S. thermophilum* strongly stimulated the extension rate of growth of mushroom mycelium (Straatsma *et al.*, 1991). The community succession pattern of microbs in mushroom compost changes along with the temperature gradients (Agrawal *et al.*, 2014).

Although fungi have the ability to degrade most of the resistant materials, fungi cannot survive in high temperatures (above 60^{o}C) as bacteria do and also have low tolerance for low oxygen environments (Fuchs, 2010). This is clear as fungi give way to only bacteria at the peak of the composting where only thermophilic fungi can survive. The fungal activity is inhibited as a result of the intense heat during the thermophilic stage of composting. During the later stage of the composting, bacteria activity paved way for the activities of fungi (Fuchs, 2010). Thus the bacteria first of all degrade the substrates and then produce 25 metabolites thereby creating a new physio-chemical environment for the fungi to continue the work (Fuchs, 2010). The activity of the fungi is impeded after the maturation stage when all the cellulose in the substrate is used up by the microbial culture. Since the fungi have a right time to effect composting, monitoring the fungal population in compost is important to determine their quality and field of application (Anastasi *et al.,* 2005). Fungi mostly take over after bacteria have started the composting process and therefore degrade the cellulose and the lignin in the compost (Agrawal *et al.*, 2014).

2.2.3. Compost timing and cultivation

In mushroom production the composting time is important to ensure the effectiveness of the mushroom which is a macro-fungus. There is therefore the need to study the composting time before inoculation to enhance easy colonization of the mycelia for fruiting. Substrate production is one of the most critical stages of cultivation of mushrooms because it has a dramatic consequence on the yield and quality of the crop and consequently the economic viability of the crop (Diego *et al.,* 2011). The main purpose of composting for preaparation of compost for button mushroom production is to preapare a substrate in which the growth of mushroom is promoted to practical exclusion of other microorganisms and also to ensure the timely release of the nutrients to the crop (Oei, 2003; Obodai *et al*., 2010). Low C: N ratio, optimum moisture content, and regular turning of substrate increase microbial activity (Nutongkaew *et al.,* 2014). The longer time interval between turnings, it takes more time for the compost to be ready. The compost pile must also be turned every three days interval to regulate aeration and moisture content. It is therefore imperative that the composting time should be managed to know exactly when to inoculate the spawns to ensure proper mycelia formation and fruiting. The fungi are not good starters of the composting process but good finishers (Fuchs, 2010). Different substrates have different composting periods (Obodai *et al.,* 2010; Markson *et al*., 2012). A lignocellulolytic mushroom such as *Pleurotus sp and Calocybe indica* can be grown on raw lignocellulosic material without composting but other mushrooms such as *Agaricus* and

Lentinula species need composting for their production (Diego *et al.,* 2011). To use straw as a substrate, the straw must first be chopped into reasonable sizes and then soaked in water for about 1-2 hours, and then it is rinsed 2 to 3 times in clean water and left for 3 to 4 hours before spawning can be done (Roy *et al.,* 2015).

2.2.4. Pasteurization of compost

Pasteurization is a partial sterilization of substrates at a temperature that destroys harmful microorganisms without major changes in the chemistry of the substrate. Pasteurization is applied to reduce weeds, diseases and pests (Kurtzman, 2010). The methods available for mushroom substrate pasteurization include; hot water treatment with boiling water for 30 minutes; chemical sterilization with formalin and pasteurization through steam by using steam drum where the plastic bags are kept in the steam drum filled with 4-5 inches bottom layer of water and heated at 80^{o}C for one hour (Dias, 2012). Steam pasteurization was found to be the best method for substrate pasteurization since substrates from steam pasteurization produced the fastest mycelia formation (Ali *et al.,* 2007).

2.2.5. Spawn and Spawn Running

Mushrooms see are known as spawn, are only pure mushroom mycelia which are growing on a sterilized grain medium (Maheshwari, 2013). Once a pure culture of mushroom is obtained, the spawn could be made from it. The spawn is the vegetative phase of mushroom on soild material. To get good quality of spawn, the most important is the quality of the inoculums. The inoculums should be fresh and pure. If the inoculums are preserved in refrigerator, they should be activated before they are used for spawn production (Thakkar, 2010; Tesfaw *et al.,* 2015). Mostly grains are used to produce spawns due to their faster ramification of the substrate and their ease of planting (Stanley *et al.,* 2010). The first stage in the production of the spawn is the culturing of the mushroom mycelia on nitrified agar media before the starter culture is used to make the grain spawn then grain spawn is used to make the final fruiting substrate (Ogden *et al.,* 2004). After the mycelia is added to the grain, the grain and the mycelia are shaken 3 times at 4 days intervals over a 14 day period for active mycelia growth. Stanley *et al.,* (2010) performed experiments on using different grains to produce mushroom spawns and then concluded that the best grain to use for mushroom spawn was white maize grain. The maize grain ensured faster mycelia growth than the red sorghum that was normally used. The factors that affect spawn preparation include CO_2, oxygen, light, pH, temperature and humidity. The time needed for the mycelia to colonize the compost depends on the rate and distribution of the spawns, the moisture content, quality and nature of the compost and temperature (Thakkar, 2010). Many factors such as mushroom cultivar used, compost factors, sanitation etc. can determine the proper spawn growth (Royse, 2014). The inoculated bags must be kept in the dark until the mycelia fully invades the substrate. The reproductive phase is reached when the mycelia fully colonize the substrate and perhaps when some nutrients run out (Thakkar, 2010).

2.2.6. Cropping of mushroom

Cropping is the developing of the mycelia into pinheads and then the fruit. Although spawn run needs dark room, high CO_2 and even a moderate humidity of about 65-70% (Thakkar, 2010), formation of pinhead and fruiting need less CO_2 of below 2% and high humidity of about 80-90% and low temperature of about 16-18^{o} C . In order to keep these conditions constant, there is the need of constant supply of ventilation to reduce the CO_2 content in the cropping room. The pinheads are too delicate that heavy watering may damage the pin head (Hasan *et al.,* 2015).

2.3. Milky mushroom*(Calocybe indica*)

The milky mushroom (*Calocybe indica*) is a potentially new species to the world mushrooms growers. This was reported first time from West Bengal in India in 1974 (Purkaystha *et al*., 1974) and its edibility was confirmed later by Purkaystha, (1976). It is suitable for hot humid climate. A substrate is an important substance for growing mushrooms. In Asia, rice straw is widely used as the substrate for cultivating oyster mushroom, (Yang *et al.,* 2016) and is also considered the best substrate for yield and high protein content. A cultivation practice of oyster mushroom in tea waste was also recorded by Yang *et al.,* (2016). This edible mushroom has a long shelf life (5-7 days) compared to other commercially available counterparts. It has become the third commercially grown mushroom in India, after button and oyster mushrooms (Purkayastha *et al.*, 1976). It can grow at temperature range of 25-40°C. Its productivity is influenced by substrate and environment factors (Kumar *et al*., 2015). Its robust size, sustainable yield, attractive color, delicacy, long shelf-life, moderate protein content and lucrative market value have attracted the attention of both mushroom consumers and prospective growers. At present this mushroom variety is being cultivated in southern India but recently its production has started in northern India. Recent literature showed that, edible mushroom *C. indica* possessed profound antioxidant, antibacterial, antitumour, antioxidant, antidiabetic and antiinflammatory activities (Selvi *et al.,* 2011). Wheat bran, rice bran, soybean flour, pigeon pea powder, black gram powder, green gram powder, lentil powder, mustard cake, neem cake, lobia powder and cotton cake were used as organic supplements. These supplements were mixed with wheat straw (Kumar *et al.,* 2012). As casing garden soil (GS), vermi compost (VC), farm yard manure (FYM) alone and in combinations can be used (Kumar *et al.,* 2012). Rice bran, maize powder, and wheat bran were used as supplements for rice straw substrate to cultivate milky white mushrooms (Alam *et al.,* 2010).

2.4. Oyster mushroom cultivation

Oyster mushrooms of the genus *Pleurotus* (Fr.) Kumm belongs to Basidiomycota are well known as valuable edible mushrooms which are broadly cultivated in the world. Mushrooms of *Pleurotus spp.* are commonly known as "oyster mushroom". These are the second most popular mushroom after button mushroom all over the world (Adejoye *et al.,* 2006). Among the oyster mushrooms *Pleurotus ostreatus* was first cultivated in Germany during the first World War and is now grown commercially around the world for food (Patil *et al.,* 2010). Due to the high nutritional value, delicate taste, and variable vitamins and minerals content, oyster mushrooms rank second in terms of industrial cultivation worldwide after a white button mushroom, *Agaricus bisporus* (Baars *et al.,* 2008). Since oyster mushrooms are secreting cellulolytic and lignolytic enzymes, they can be used for biotechnological purposes (Sanchez, 2010). A wide range of substrates including wheat straw, barely straw, sinar straw and saw dust banana leaves, bean straw were used for *P. ostreatus* cultivation (Tesfaw *et al*., 2015; Iqbal *et al.,* 2016; Manimuthu *et al.,* 2015; Raina *et al*., 2014). Supplements are additives which increase the yields by providing specific nutrients for the growth of the mycelium (Khare *et al.,* 2010; Tesfaw *et al.,* 2015). Supplements increase the risk of contamination at least by 25% (Yildiz, *et al.,* 2002). Tesfaw *et al.,* (2015) also stated that supplements change physical conditions of substrates more suitable for cultivation of mushrooms. Addition of supplements (rice husk) to waste paper significantly increase spawn running, pin head formation, fruit body formation and mushroom yield (Tesfaw *et al.,* 2015, Ruiz-Rodriguez *et al.,* 2010). The substrates used for cultivation of oyster were used again for other cultivation. The reused of substrates that contained additional supplements exhibited better growth on both pasteurized and sterilized substrates (Tesfaw *et al.,* 2015).

2.5. Nutritional value of mushrooms

Mushroom is considered to be a complete, health food and suitable for all age groups, child to aged people. The nutritional value of mushroom is affected by numerous factors such as species, stage of development and environmental conditions. Mushrooms are rich in protein, dietary fiber, vitamins and minerals (Chakravarty, 2011; Da Silva, 2012, Thatoi *et al*., 2014). Mushrooms are good source of protein, vitamin and minerals (Alam *et al.*, 2008). It has protein (25-30%), fat (2.5%), sugar (17-44%), mycocellulose (7-38%) and mineral; (potassium, phosphorus, calcium and sodium) of about 8-12% (Stanley, 2011). The nutritional constituent depends upon the substrate on which they are cultivated (Alam *et al., 2*007; Chakrabort *et al.,* 2016). Cultivated mushrooms have higher protein contents and minerals, low in fat and rich in vitamin B, D, K, sometimes the presence of vitamins A and C were also reported (Manzi *et al.,* 2001). Mushrooms contain 18 essential amino acids such as methionine, isoleucine, lysine, glutamic acid, cysteine, aspartic acid phenylalanine, tyrosine, tryptophan, valine, arginine, histidine, alanine, glycine serine and proline (Djarijah *et al.,* 2001). Mushrooms are also rich in essentials unsaturated fatty acids including oleic, linoleic, alfa-linolenic and palmitic acids. Nutritive values of different mushrooms are given in Table 2 & 3.

Table2. Nutritive values of different mushrooms (dry weight basis g/100g)

Mushroom	**Carbohydrate**	**Fibre**	**Protein**	**Fat**	**Ash**	**Energy k cal**	**Reference**
Agaricus bisporus	46.17	20.90	33.48	3.10	5.70	499	Kalac, 2009
Pleurotus sajor-caju	63.40	48.60	19.23	2.70	6.32	412	kalac, 2009
Lentinula edodes	47.60	28.80	32.93	3.73	5.20	387	kalac, 2009
Pleurotus ostreatus	57.60	8.70	30.40	2.20	9.80	265	Barros 2008
Volvariella volvaceae	54.80	5.50	37.50	2.60	1.10	305	Barros 2008
Calocybe indica	64.26	3.40	17.69	4.10	7.43	391	Manzi 1999
Flammulina velutipes	73.10	3.70	17.60	1.90	7.40	378	Manzi 1999
Auricularia auricula	82.80	19.80	4.20	8.30	4.70	351	Manzi 1999

Table3. Essential amino acid composition of some edible mushrooms

Mushroom species	Valine	Leucine	Isoleucine	Threonine	Methionine	Lysine	Phenyl alanine	Tryptophan	Reference
Agaricus bisporus	2.5	7.5	4.5	5.5	0.9	0.1	4.2	2.0	Rahi *et al.*,2016
Lentinus edodes	3.7	7.9	4.9	5.9	1.9	3.9	5.9	Nd	Bano *et al.*,1982
Pleurotus florida	6.9	7.5	5.2	6.1	3.0	9.9	3.5	1.1	Bano *et al.*,1982
Volvariella diplasia	9.7	5.0	7.8	6.0	1.2	6.1	7.0	1.5	Bano *et al.*,1982 Rahi *et al.*,2016
V. volvacea	5.4	4.5	3.4	3.5	1.1	7.1	2.6	1.5	Bano *et al.*,1982, Rahi *et al.*,2016
P. ostreatus	0.91	1.13	0.62	1.10	0.28	0.71	0.73	0.15	Rahi *et al.*,2016
P. sajor-caju	0.98	1.3	0.75	0.98	0.34	0.78	0.86	0.09	Rahi *et al.*,2016

Note. Values are expressed on dry weight basis (µg/100g of sample)
Nd- not determined.

2.6. Medicinal and therapeutic value of mushrooms

2.6.1. Bioactive compounds detected in edible mushrooms

Mushrooms are also recognized as an important source of biologically active compounds (Alves *et al.,* 2013; Vasundhara *et al.,* 2016). *A.bisporus* has many medicinal metabolites responsible for the therapeutic activity for which the treatment and prevention of many human diseases act as anti-cancer agents such as polysaccharides, fatty acids and ergosterol, N,N,Ntris" hydrazine carbonyl" phosphoric triamide, selenium and vaccenic acid; anti-hyper cholesterol agents such as fatty acids, glycoproteins, sterols and vaccenic acid (Hammann *et al.,* 2016); anti-microbial agents (Cristiane *et al.,* 2016) anti-cardiovascular disease metabolites such as fatty acids, sterols and pyran derivative hepato protective agent triterpenoids (Hammann *et al.,* 2016) uman health supporting agent's (fatty acids,sterols and sugar alcohols); immune enhancer metabolites like fatty acids, glycoproteins, polysaccharides and sterols (Hammann *et al.*,2016; Jananie *et al.,* 2012). These medicinal metabolites such as β-glucan and G-glucan; polysaccharide K or PSK "protein bound polysaccharide; phenols; polyketides, triterpenoids and sterols (De Barros, 2008); triterpenoids, lectins glycoprotein's, ergothioneine (Ey *et al.*, 2007) selenium, pyran derivative, essential fatty acids (Andersson *et al.,* 2004; Ji *et al.,* 2006). Mushrooms have not just been consumed for their culinary importance because of their unique taste and flavour

(Kalac, 2013), but also because of their potential therapeutic properties as well as effective to treat and prevent varieties of disorders (Moro *et al.*, 2012; Paul et al., 2017). These bioactive metabolites include phenolic compounds, terpenoids, polysaccharides, lectins, steroids, glycoproteins and several lipid components (Reis, 2012). Several studies have been conducted to evidence the bioactive properties of mushroom extracts as well as of their secondary metabolites such as antioxidant (Heleno *et al.*, 2015), antitumour (Ferreira *et al.*, 2010), antimicrobial (Alves *et al.*, 2013), immunomodulator, antiatherogenic, hypoglycemic and anti-inflammatory (Han *et al.*, 2013; Moro *et al.*, 2012; Choi *et al.*, 2014; Taofiq *et al.*, 2015) activities. Mushrooms are also considered as functional foods because they elicit their positive effect on human being (Patel *et al.*, 2012).

Table4. Source, type, and bioactivity of some polysaccharides isolated from different edible mushrooms

Mushrooms	Polysaccharide source	Type of polysaccharide	Bioactivity	Reference
Pleurotus tuber-regium	Sclerotium, mycelium	Beta-glucan	Hepatoprotective and antibreast cancer	Zhang *et al.*,(2007)
Ganoderma lucidum	Fruit body, culture broth	Heteroglycan, Mannoglucan, Glycopeptides	Hyperglycemia, Immunomodulating, antitumor, antidecrepitude	Zhang *etal.*,(2007) Rahi *et al.*,(2016)
Lentinus edodes	Culture broth, fruiting body	Mannoglucan, polysaccharide-protein complex, glucan, lentinan	Immunomodulating, antitumor, antiviral	Zhang *et al.*,(2007)
Agaricus blazei	Fruit body, mycelium	Glucan, Heteroglycan, glucan protein, Glucomannan-protein complex	Antitumor	Zhang *et al.*,(2007) Rahi *et al.*, (2016)
Ganoderma applanatum	Fruit body	Glucan	Antitumor	Zhang *et al.*,(2007)
Polyporus umbellatus	Mycelium	glucan	Antitumor, immunomodulating	Zhang *et al.*,(2007)
Pleurotus citrinopileatus	Fruit body	galactomannan	Antitumor	Zhang *et al.*,(2007)
Pleurotus ostreatus		Glycoprotein	Antitumor, hyperglycemia, antioxidant	Zhang *et al.*,(2007)
Volvariella sp	Fruit body,	Polysaccharides	Cardiac tonic	Chang *et al.*,(2004)
Trametes coriolus	Fruit body, mycelium	Polysaccharide, PSP-a glycopeptides	Antitumor and Immunostimulant	Chang *et al.*,(2004)

Tricholomopsis rutilans	Fruit body, mycelium	Polysaccharides	Anticarcinogenic activity Antioxidative and anti inflammatory	Chang *et al.*,(2004)
Morchella esculenta	Fruit body	Heteroglycan	Hyperglycemia, antitumor	Zhang *et al.*,(2007) Rahi *et al.*,(2016)
Tricholoma mongolium	Fruit body	Glucan	Antitumor activity	Zhang *et al.*,(2007)

Table5. Therapeutic metabolites of different edible mushrooms and their bioactivity

Mushrooms	Compounds	Medicinal properties	Reference
Ganoderma lucidum	Triterpenes	Active against HIV	Nahata (2013)
	Ganoderiol F Ganodermanontriol Ganodermadiol	Cytotoxic to hepatoma cells, protection against atherosclerosis,	Chang *et al.*,(2004) Nahata (2013)
	Ganopoly	Hypoglycemic effect	Rahi *et al.*,(2016)
	Ganoderon B	Antitumor activity	Lin *et al.*,(2010)
	Glycoprotein	Augments immuno-system, antitumor	Wang *et al.*,(2007) Moradali *et al.*,(2007)
	Ganoderic acid B Beta-glucans	activity, Liver protection, Antibiotic properties, Inhibit cholesterol sysnthesis	Rahi *et al.*,(2016)
Ganoderma frondosa	Polysachharides Lectins	Increase insulin secretion Decrease blood glucose	Rahi *et al.*, (2016)
Lentinula edodes	Eritadenine (derivative of nucleotide)	Antilipidemic activity Anticancer agent	Rahi *et al.*, (2016) Nahata (2013)
	Lentinan	Antibacterial activity	Nahata (2013)
	Oxalic acid present on caps	Inhibits sarcoma 180 and HIV induced cytopathic effect	Nahata (2013)
	Emitanin Soluble lignin	Used in tumor/ chemo/ radiotherapy/surgery Anti HIV activity	Nahata (2013)
Agaricus bisporus	Lectins	Enhance insulin secretion Immunomodulatory	Ahmad, (2014) Chang *et al.*, (2004)
	Conjugated linoleic acid	Anti-carcinogenic and anti-mutagenic activity Anti-proliferative activity Antioxidant activity Tumor-suppressive activity	Adams *et al.*, (2014) Nahata (2013) Gan *et al.*, (2013) Sharma *et al.*,(2016) Kim *et al.*, (2014)
Agaricus brasiliensis	L-ergothionene	Antioxidant activity	Gan *et al.*, (2013)
Calocybe indica	Glucan	Antiinflamatory activity	Prabu *et al.*, (2014) Selvi *et al.*, (2010)
P. pulmonarius	Saponins	Antiinflamatory activity	Josh *et al.*, (2004)
Pleurotus florida	Glucan Pleuran	Antiinflamatory activity	Josh *et al.*,(2004)

Contd….

Mushrooms	Compounds	Medicinal properties	Reference
P. Sajor-caju	Lovastatine Proteins having polysaccharide xyloglucan, xyloproteins	Lower cholesterol Antitumor activity	Gunde *et al.*,(1999) Rahi *et al.*, (2016)
Pleurotus ostreatus	Aqueous Polysaccharides Polyphenols Ubiquitine Glucan Pleuran Ribonucleases Lovastatine	Induces anti-proliferative and pro-apoptotic effects on colon cancer cells Antioxidant activity Anti-viral activity Antiinflamatory activity Neutralize HIV by degrading genetic materiall Artherosclerotic activity	Lavi *et al.*,(2012) Ivette *et al.*, (2016) Pumtes *et al.*, (2016) Zhang *et al.*, (2007) Josh *et al.*, (2004) Nahata (2013) Rahi *et al.*, (2016)
P. citrinopileatus	Homodimeric Lectin	Anti-tumor activity	Li *et al.*, (2008a)
P. tuber-regium	Water soluble Polysaccharides	Anti-proliferative activity	Wong *et al.*, (2007)
Pleurotus flabellatus	Phenolics Lycopene, alpha-tocopherol and L-ergothionene	Antioxidant activity	Pumtes *et al.*, (2016) Adhiraj *et al.*, (2014) Vamanu, (2013) Vangkapun *et al.*, (2011)
Auricularia auricula	Acidic Polysachharides	Decrease blood glucose	Yuan *et al.*,(2008)
Flammulina velutipes	Ergothioneine Proflamin Velutin protein Enokipodins Sesquiterpenes	Antioxidants Anticancers activity Antitumor, antifungal and anti bacterial activity	Pumtes *et al.*, (2016) Nahata (2013) Nahata (2013)
Trametes versicola	Polisachharide-k (kresin)	Decrease Immuno-system depression	Chang *et al.*, (2004)
Cordyceps sinensis	Cordycepin Adenosine, ergosterol	Cure lung infections, Hypoglycemic activity, Cellular health properties Antidepressant activity Antioxidative property	Li *et al.*,(2007) Rahi *et al.*,(2016) Lavi *et al.*,(2012) Pumtes *et al.*, (2016)
Pleurotus tuber-regium	Water insoluble Glucans	Antiviral activity	Zhang *et al.*, (2007)
Auricularia polytricha	Antiplatetet compound Adenosine	Artherosclerotic activity	Nahata (2013)

2.6.2. Antimicrobial properties of mushroom

Inhibitory activity of methanolic extract of *Pleurotus sp* against *Bacillus megaterium*, *S. aureus, E. coli, Klebseilla pneumonia, Candida albicans, C. glabrata*, species of *Trichophyton* and *Epidermophyton w*as demonstrated to different degrees that were lower with respect to two antifungal agents' streptomycin and Nystatin (Akyuz *et al.,* 2010). Ether and acetone extracts of oyster mushroom was effective against *B. subtilis*, *E. coli* and *S. cerevisiae, Pseudomonas aeruginosa* (Nithya *et al.,* 2009). Extract of *A. bisporus* has the antibacterial activity against a wide rane of pathogenic bacteria as well as fungi (Sharareh *et al*., 2016, Waithaka *et al*., 2017). Parashare *et al.,* (2013) reported that mushroom extract showed the antibacterial activity against *Staphylococcus aureus*, *Escerichia coli* and *Pseudomonas.*

2.6.3. Anti-tumor activity

Lavi *et al.,* (2006) reported an aqueous polysaccharide, extracted from *P. ostreatus* induces anti-proliferative and pro-apoptotic effects on colon cancer cells. The water soluble polysaccharide from *P. ostreatus* was considered as a potential candidate for developing a novel low-toxicity anti-tumor agent (Maiti *et al*., 2011). Li *et al.,* (2008a) isolated a homodimeric lectin from fresh fruiting bodies of *P. citrinopileatus* and reported as considered as potent anti-tumor activity in mice bearing sarcoma. Wong *et al.,* (2007) studied the in vitro anti-proliferative activities of the water soluble polysaccharides extracted from fruit body and mycelium of *Pleurotus tuber-regium* where fruit body extract showed the strongest cytotoxicity and anti-proliferative activity. The extract Immunomodulatory, anticarcinogenic and anti-mutagenic properties of *Agaricus* sp have studied by Delmanto *et al.,* (2001). Lectin from *Agaricus bisporus* and *Agaricus polytrica* protein are stable immuno-stimulants (Chang *et al.,* 2010). Kim *et al.,* (2014) reported that the extract from *Agaricus sp* showed the most potent tumor selective growth inhibitory activity against human leukemia. Adams *et al.,* (2014) evaluated the effect of *A. bisporus* extract in vivo and its major component conjugated linoleic acid on prostate cancer cell lines in vitro and reported that the extracted linoleic acid inhibited proliferation in the prostate cancer cell lines in vitro.

2.6.4. Antioxidant activity

The antioxidant activity of *Agaricus bisporus* was determined by means of DPPH and TCA, and H_2O_2 assay (Waithaka *et al*., 2017). High phenolics and flavonoid content in *Pleurotus flabellatus* have been detected by Pumtes *et al.,* (2016). The phenolic and flavonoid content has an impact on antioxidant activity (Pumtes *et al.,* 2016). Mushrooms containing high phenolics compound are normally well correlated with antioxidant activity (Ahmad *et al.,* 2014). The phenolic content are among the phenolic compounds in mushrooms such as phenolic acids, gallic acids, caffeic acid, quercetin, flavonoids ant tannins, in which the phenolic hydrogen is a major contributor to antioxidant activity (Siu *et al.,* 2014). In mushrooms gallic acids, ascorbic acids, beta-carotene, Lycopene, alpha-tocopherol and L-ergothionene are the main compounds with antioxidant effect (Vamanu, 2013, Vangkapun *et al.,* 2011). Adhiraj *et al.,* (2014) reported *P. flabellatus* can be a potential source of natural antioxidant to treat variuor oxidative stress related diseases. Antioxidant activity of *Agaricus bisporus* and *Agaricus brasiliensis* was determined by Gan *et al.,* (2013). Phenolics are considered to be beneficial antioxidants as they exhibit scavenging activity of harmful active oxygen species (Jiang *et al.,* 2015). Mushroom *Pleurotus ostreatus* contains high protein, vitamin and mineral contents very lower amount of carbohydrates sugar and very less amount of cholesterol (Patel *et al.,* 2012). However Gil-Ramirez *et al.,* (2016) reported that the mushrooms do not contain flavonoids and those found in the hyphae could be due to the facility of these organisms to absorb many nutrients and compounds from the substrate where they grow or from neighboring plants by spreading their hyphae. All water and methanolic extract of *Pleurotus ostreatus* possess phenolics compound and flavonoid and they suggested that the antioxidant activity could not be by poly phenol. The antioxidant activity may be as a result of the presence of others molecules which are present in the extract (Ivette *et al.,* 2016). He also investigated the antioxidant properties of aqueous and 95% ethanol extracts of two species of fungi, *Pleurotus ostreatus* and *P. sajor-caju,* obtained from a local farm in Thailand. The aqueous extracts showed the highest amount of total polyphenols and better antioxidant activity than ethanol extracts for both fungi. Kim *et al.,* (2014) investigated the antioxidant activity and the total polyphenol amount, of methanol extracts of mycelium and fruiting body of *P. sajor-caju*, *P. ostreatus* and *P. sapidus*. The polyphenolic compounds with antioxidant activity are multifunctional and act according to the majority of these mechanisms. Furthermore, it is known that the antioxidant properties depend on the type of solvent used in the extraction and complexity of compounds, since must involve different methods to determine their antioxidant activity. Fruiting bodies of *Pleurotus* possessed higher concentration of antioxidants than other commercial mushrooms (Lo, 2005). Oyster mushrooms are now widely used as ingredients in dietary supplements in the hope of maintaining health and preventing diseases due to their higher free radical scavenging activities (Kim *et al.,* 2004). Fruiting bodies of oyster mushroomhave higher phenol concentration when compared with mycelium and fermentation broth filtrate of *P. citrinopileatus* (Jose *et al.,* 2004).

2.6.5. Anti-inflamatory activity

Pleuran, isolated from fruiting bodies of oyster mushroom possesses antiinflammatory activity. Extracts of many of *P. florida, P. pulmonarius* give a lowering response in both acute as well as in chronic inflammation (Jose *et al.,* 2004). Nozaki *et al.* (2008) reported the mechanism that glycosphingo-lipid isolated from *P. eryngii,* induced secretion of IFN-g and IL-4 from T-cells, whereas (1-3), (1-6)-linked-glucan isolated from *P. ostreatus* inhibited leukocyte migration to acetic acid-injured tissues. Recently a nonlectin glycoprotein isolated by Chen *et al.*, (2011) from fresh fruiting body of *P. citrinopileatus* down-regulated the pro-inflammatory mediators. In their experiments they also observed that anti-inflammatory activity of oyster mushroomthat was mediated through the inhibition of NF-kB and AP-1 signalling. Another potent anti-inflammatory agent, a polysaccharidehas been extracted from the *P. pulmonarius* that acted against carrageenan and formalin-induced paw edema in rats (Adebayo *et al.*, 2014). Tannin and terpenes concentration detected in the mushroom have been found to possess astringent properties, which hasten the healing of wounds and inflamed mucous membrane (Okwu, 2004). *C. indica* extract inhibited the proteinase trypsin and display the most potent inhibitory activity of proteinases as reported by Prabu *et al.,* (2014). Jose *et al.*, (2004) reported that methanolic extracts of *Pleurotus pulmonarius* and *Pleurotus florida*cause decrease of induced paw edema and ameliorated acute inflammation in mice. Ajith *et al.*, (2001) found that the methanolic extract of *Phellinus rimosus* (Berk.) Pilat inhibited significant antiinflammatory activity in acute and chronic inflammations in mice. Selvi *et al*., (2010) studied that the aqueous and ethanolic extracts of *C. indica* for its antilipid-peroxidative activity through *in vitro* model of goat.

2.6.6. Antiviral activity of mushrooms

Pleurotus mushroom contain substances that exert direct or indirect antiviral effects as a result of immune-stimulatory activity. Ubiquitin, an anti-viral protein was isolated and identified from fruiting body of oyster mushroom (Selvi *et al*., (2010). Water-insoluble-glucans isolated from sclerotia of *P. tuber-regium* and their corresponding water-soluble sulphated derivatives were active against herpes simplex virus type-1 and type-2 (Zhang *et al.*, 2007). The anti-viral activity was due to binding of sulphated-glucans to viral particles thereby preventing them from infecting the host cells. Not only intracellular proteins of *P. ostreatus* but its extracellular extract also contains polysaccharides that have Immuno-modulating effects.

2.6.7. Anti-ageing activity

Extracts of *P. abalonus and P. ostreatus* elevated levels of vitamin C and E, increased activities of catalase, superoxide dismutase and glutathione peroxidase in aged rats (Jayakumar, 2009). Different extracts (methanol, ethanol, acetone or water extract) of *Pleurotus* can improve the antioxidant status during ageing leading reducing the occurrence of age-associated disorders like stroke, Parkinson's disease, atherosclerosis, diabetes, cancer and cirrhosis. The polysaccharides from mushrooms are potent scavengers of super oxide free radicals. This antioxidant prevents the action of free radicles and consequently reducing the ageing process.

2.6.8. Hepatoprotective activity

Chen *et al.*, (2014) reported the hepatopreventive and therapeutic activity of hot-water extract of mushrooms by mechanism of inhibition through preventive regimen caused less leakage of alkaline phosphate, less pronounced increase in hepatic malodialdehyde concentration, less notable reduction in hepatic total protein, RNA and DNA contents and in contrast increased hepatic superoxide dismutase, glutathione reductase activity, glutathione peroxidase activities. Polysaccharides extracted from fruit body of *P. ostreatus* alleviated the thioacitamide-induced alterations, inflammation, steatosis necrosis and fibrosis in the therapeutic regimen as reported by Chen *et al.*, (2014). He also observed that water soluble polysaccharides extracted from *P. eryngii* removes the free radicals and also increase the activity of the antioxidant enzyme in liver injury mouse model.

2.6.9. Anti HIV properties of mushrooms

Ribonucleases have been isolated and characterized from the *P. ostreatus* that has the potentiality to neutralize HIV through degradation of viral genetic material (Wang *et al.*, 2012). Oyster mushrooms have been reported to have a nopvel ubiquitin-like protein having HIV-reverse transcriptase inhibitory activity (Wang *et al.*, 2005). Similarly hot water extracts of *P. sajor-caju* and *P. pulmonarius* inhibit HIV-1 reverse transcriptase activity by SU2 (Wang *et al.*, 2007). A Lectin isolated from fresh fruiting bodies of *P. citrinopileatus* also inhibited HIV-1 reverse transcriptase (Li *et al.,* 2008a).

2.6.10. Anti-mutagenic activity

Extracts of 89 different mushrooms species were tested for their antigenotoxic and bio-antimutagenic activities on *S. typhimurium* and *E. coli* and mushroom extracts was found to be most effective. Methanolic extracts of *P. ostreatus* showed significant inhibition of mutagenicity elicited through mutagens requiring activation (Lopez *et al*., 2016). Dried *P. ostreatus*, in diet, reduced pathological changes in dimethylhydrazine-induced colon cancer, in rats. Furthermore, extracts of *P. cornucopiae* significantly reduced HO^- induced DNA damage in Chinese hamster lung cells and *P. ostreatus* extract mitigated genotoxicity through suppression of DNA damage induced by different mutagens in the *Drosophila DNA* repair test. *P. citrinopileatus* fruiting body extracts have shown antioxidant activities *in vitro* and in hyperlipidemic hamster rats. Li *et al.*, (2007) observed up-regulated gene expression of antioxidant enzymes and consequently their activities were increased.

2.6.11. A new source of compounds with potential hypocholesterolemic activity

The World Health Organization estimated that 17.3 million lives were lost in 2008 and an expected 23.6 million people will die of cardiovascular diseases by the year 2030. About 80% of mortality rates were reported from the lower and middle income countries. The treatment of hypercholesterolemia is targeted by decreasing the low density lipoprotein by medications. A wide variety of biological active compounds are produced by fungi (De Silva *et al*., 2012a, 2012b, 2013) including statins (anti-cholesterol compounds). Lovastatin is an interesting fungal metabolite. It functions as a competitive inhibitor of the enzyme, 3-hydroxy-3methyl-glutaryl enzyme in cholesterol biosynthesis. HMG Co-A reductase is an important enzyme in the process of converting HMG CoA to mevalonate. Mushrooms fruiting bodies or their extracts might be considered as a new source of compounds with potential hypocholesterolemic activity because they are rich in ergosterol-derivatives, β-glucans and HMGCoA-red inhibitors. The presence of lovastatin in the mushroom *Pleurotus ostreatus, P. saca and P. sapidus* was confirmed by Cimerman, (2006) and Radha *et al*., (2013), Dhar *et al.,* (2015). *Agaricus campestris, C. indica, Ganoderma applanatum* and *Tricholoma giganteum* also prooduced lovastatin (Pushpa *et al.*, 2016). The presence of lovastatin in *Pleurotus* has been reported by Mowsumi *et al.,* (2013). Choudhury *et al.,* (2013) reported that the intake of *P. ostreatus* improves glycemic status and effective in controlling blood pressure in diabetic hypertensive subjects.

2.6.12. Mushrooms as pre-biotics

Mushrooms are highly nutritive with high content of carhohydrate, protein, vitamin, fibers, and low in cholesterol (Thatoi *et al*., 2014). Recently many research studies revealed that the mushrooms contain some polysaccharides that have been successfully used as nutraceuticals (Giannenas *et al*., 2011). Among these edible mushrooms, *Pleurotus eryngii, L. edodes* and *Flammulina velutipes* contain ribose, xylose, fructose, mannose, glucose and trehalose (Kim *et al.,* 2014). Different mushrooms produce different types of polysaccharides that can be either water soluble or water insoluble. Some polysaccharides have only glucose moiety while some have proteins attached with them. Polysaccharides are mostly β-linked glucose molecules but some also have galactose and mannose; yet some are heteropolysaccharides and others are glucan-protein complexes. These polysaccharides can beutilized in treatment of simple to complex diseases like cancer, AIDS and other present day diseases (Ooi *et al.,* 2008). The balance of intestinal flora is crucial for human health and disease prevention. In this context, prebiotics are the most promising health foods because they can regulate the structure and number of intestinal flora. Mushrooms (*P. ostreatus* and *L. edodes*) can significantly modify intestinal flora composition by promoting the metabolismandproliferation of beneficial microorganisms suchas *Lactobacilli* and *Bifido-bacteria*, as well as by inhibiting pathogenic bacteria such as *E coli, Clostridium* and *Salmonella* (Zhou *et al.,* 2011). The major components rendering prebiotics function in mushroom are non-digestible polysaccharides such as glucan, chitin and hetropolysaccharides. Mushrooms also prevent viral infection by enhancing the growth of probiotic bacteria in the large intestine (Villares *et al.,* 2012). Several mushroom polysaccharides likepleuran, lentinan, schizophyllan, β and α- glucans, mannans, xylans, galactans, chitin, inulin and hemi-celluloses can be credited to promising prebiotics effects. Pleuran from *P. ostreatus* and lentinan from *Lentinus edodes* mushrooms are currently the most frequently used β-glucans as prebiotics. Both of them show positive effects on the intestines. They increase the resistance of intestinal mucosa to inflammation and inhibit the development of intestinal ulcers in rats Lentinan also shows a positive effect on peristalsis in weaned piglets (Van *et al.,* 2003).

2.7. Spent mushroom Compost as Soil Conditioner and Organic Fertilizer

Spent mushroom compost is a noxious byproduct of mushroom farming (Tuhy, 2015). Jonathan *et al.,* (2012) considered SMS as remnant substrate of cultivate mushroom.

The use of organic manure such as spent mushroom substrate in growing agricultural crops especially leafy vegetables has been recognised in recent times as a possible means of enhancing sustainable agriculture or sustainable production of food crops (Okokon *et al.*,2009). Ezugwu *et al.,* (2000) who worked on the influence of organic manure rates and inorganic fertilizer formulations on some quantitative parameters of fluted pumpkin stated that the SMS can be used as an alternative of inorganic fertilizer. Tuhy *et al.,* (2015) obtained healthy effect when he conducted an experiment on tomato plants. SMS contribute significantly to the number of branch, number of leaves in the vegetables depending on the rate of application (Saalu *et al.,* 2010; Roy *et al.,* 2015). According to Akanbi *et al.,* (2015) organic fertilizer improved cell activity, enhance cell multiplication and enlargement of fluted pumpkin. Organic manure is known to be capable of activating diverse microorganisms which release hormones like substances that stimulate nutrient absorption and plant growth (Arisha *et al.,* 2003). Spent mushroom compost is rich in organic matter and constitutes an important source of macro-micro nutrients for plants and microorganisms thereby increase the soil micro flora, soil biological activity and enhance soil enzyme activity (Debosz *et al.,* 2002; Crecchio *et al.,* 2001). It contains calcium carbonate which provides short term buffering of the acidic water and elevates soil pH. The SMC is able to bind mineral particles together promoting a good soil structure and improving aeration and moisture retention (Piccolo *et al.,* 1994). Use of SMC in reduces the quantity of biodegradable waste disposed in landfill sites and also transforms them into economical useful agricultural product. The significant influence of SMS on the yield of Telfaira revealed that SMS can be used as soil amendment to promot the yield of crop (Dauda *et al.,* 2008). Applications of SMS of *Pleurotus ostreatus* have a direct effect on the growth and yield of *T. occidentialis* (Orluchukwu, 2016). SMS of *Calocybe indica* has direct effect on growth parameters of leafy vegetables (Barman *et al.,* 2015). Addition of leached SMC to growing media significantly improved the cucumber plants growth as recorded by Gonani *et al.,* (2011). Jonathan *et al.,* (2011) used SMC of *Pleurotus pulmonarius* as possible organic fertilizer for the improvement of growth of vegetables in Nigeria. SMC could be applied greenhouse soil at agronomic rates without heavy metal and salinity defects. SMS also effect on nutritional constituents of vegetables fruits (Priadi *et al.,* 2016). His study also showed that growing media containing SMS is the best to improve seedlings growth.

2.8. Appropriate uses of spent substrate or compost in plant disease management

SMS is excellent to spread on top of newly seeded lawns. The SMS provides cover against birds eating the seeds and will hold the water in the soil while the seed germinate. Since some plant and vegetables are sensitive to high salt content in soil, avoid using fresh substrate around these plants. In these case 6 months or more weathered spent substrate can be used. As a soil amendment, SMS adds organic matter and structure to the soil. Spent substrate primarily improves soil structure and provides nutrients. Spent substrate is the choice ingredients by those companies making the potting mixture solid in garden centres. Plant diseases like *Pythium*-damping off, apple scab, cucumber anthracnose caused by fungal pathogen was suppressed by water extract of SMS treatment (Parada *et al*., 2012). Mushroom mycelial leachate was applied as biocontrol agents to control plant diseases like bacterial wilt of tomato. Water extract of SMS play an important role to induce expression of systemic acquired resistance (SAR) related to defense genes in plants (Parada *et al*., 2011). Kwak *et al*., (2015) used water extract of SMS as an eco-friendly disease control agents. SMC extract was successfully applied as bio-control agents to suppress the *Fusarium* wilt of tomato by Adedeji *et al.*, (2016). Antagonistic activity of SMC extract against abroad range of plant pathogens have been demonstrated by Verma *et al*., (2017). Up to 55% disease index was reduced by the treatment of spent mushroom compost against *Fusarium oxysporum* in tomato plant. Apple scab disease was managed by water extract of spent mushroom compost in filed condition. Disease severity caused by *Fusarium oxysporum, Sclerotium rolfsii* and *Rhizoctonia bataticola* was maintained by treatment of SMS (Ahlawat *et al.,* 2011). The microbial diversity of *Pseudomonas* and *Bacillus present* in SMS exert antagonism to a number of soil pathogens (Mohapatra *et al.,* 2011). Spent mushroom substrate (SMS) having bio-agents, supply nutrition to the soil as well as helps in management of soil-borne plant pathogens (Verma *et al*., 2017). The presence and antagonism of different fungal microorganisms has been worked out by Verma *et al*., (2017) in which they have reported that the organic substrates such as spent mushroom compost can suppress a variety of plant pathogenic fungi including soil borne pathogens like *Rhizoctonia spp.* and *Pythium spp.*