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UTILIZATION OF AGRO-INDUSTRIAL WASTE BY HIGHER MUSHROOMS: MODERN VIEW AND TRENDS

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ABSTRACT

Waste management and providing a world population with rich in protein food are two important problems of which the utilization of agro-industrial (agriculture and food industry) waste by higher mushrooms causes the growing interest of researchers around the world. More than 150 individual types of wastes have been investigated last decade as alternative substrates alone or in various compositions (more than 450 substrates) for cultivation of 52 higher mushroom species (about 100 strains) as evidenced by the results of more than 130 considered in the review scientific publications. All waste is used as a basis for substrates and supplements thereto, are characteristic of the respective continent and region of the world. Publications containing biochemical studies of substrates and fungi confirm that fungi are grown in rich in biologically active substances unconventional substrates, provide a rich biochemical composition of fungi compared with conventional substrates (sawdust, straw, etc.). The disadvantage of many publications is the lack of mention of examined fungi strains, whereas studies of various strains of the same fungus in the same substrate show different results. The prospect of the study of agricultural residues utilization by higher mushrooms consists in the investigations of: productivity, biological efficiency of the process, morphological and biochemical indices of cultivated mushrooms, depending on the biochemical parameters of substrates and the process conditions; safety of cultivated mushrooms.

Keywords: Agro-industrial waste; higher mushrooms, utilization; substrate

INTRODUCTION

Among the world's major problems – providing a rapidly growing world population with food and waste management, including not least the agro-industrial residues (agriculture and food industry). The aim of FAO's program on the Promotion and development of non-wood forest products (NWFP) is to improve the sustainable use of NWFP in order to improve income-generation and food security, to contribute to the wise management of the world's forests and to conserve their biodiversity. One of the important group of NWFP is mushrooms. The FAO report author (**Boa, 2004**) did not took into account that world population increased on over 800 million people the last decade and reached 7.25 billion. The planet's climate is changing, and not for the better. Under these conditions, to count on mushroom wildlife resources as food, speaking at the same time about the preservation of biodiversity, is impossible. The problem of protection of the natural mushroom flora can be solved by the artificial cultivation of fungi. Wood waste (sawdust, conifer waste) is the traditional substrate for mushroom cultivation (**Stamets and Chilton, 1983; Croan, 2004; Moonmoon *et al.*, 2010; Peng, 2010; Khan *et al.*, 2012**). The using of wood waste for mushroom cultivation has two major shortcomings. A number of researchers indicate lower results of cultivation on sawdust and lower nutritional value of mushrooms in comparison with other using agro wastes (**Onuoha *et al.*, 2009; Ukoima *et al.*, 2009; Tripathy *et al.*, 2011; Govindaraju *et al*,. 2013; Dehariya and Vyas, 2013**). Furthermore, many forest trees are toxic and allergenic (**Meier, 2013**). Among substrates alternative to wood waste **Stamets and Chilton** (**1983**) mentioned for spawn making and fruit body production sugarcane bagasse, cereal straw, rye bran, rye grain, wheat bran, wheat grain, farm yard manure and some others. Meanwhile, the growth of agricultural waste in the last decades of the XX century, have attracted the researchers attention to this type of potential cheap substrates for the cultivation of mushrooms. Numerous studies have been summarized by **Poppe** (**2000**). More than 150 kinds of wastes have been proven to be useful for 45 mushroom species growing. But some listed wastes can be re-divided into at least 100 individual types of wastes. In his next worldwide survey on waste that can be used as a substrate in the Oyster mushrooms cultivation **Poppe** (**2004**) named near 90 residues (not only agro-industrial, but some forestry and industrial). In some cases, was noted the possibility of cultivation the other species of fungi in this or that waste. Last decade the situation with the aforementioned important world problems worsened. The number of undernourished and hungry people has not decreased but at the same time one third of food produced for human consumption is lost or wasted globally – a total 1.3 billion tons a year (**European Commission. Press release, 2014**).

Hundreds of studies devoted to the cultivation of mushrooms on agricultural waste have been carried out, but their ordering and review was not conducted. **Mane *et al.*** (**2007**) presented an overview of 26 substrates reported to be useful for the cultivation of various *Pleurotus* species (only 8 – in publications after 2000), 8 substrates and 44 combinations of these substrates and 3 additives for *P. sajor-caju* cultivation. The basic plant substrates that can be used for *Pleurotus* spp. cultivation are sawdust, wheat straw, rice husk, Mango, Jackfruit, Coconut, hulls, straw, stalk , paper, corn cobs, waste cotton, leaves and pseudo stem of banana, water hyacinth, duck weed, rice straw etc. (**Josephine, 2015**). Mini-review by **Kulshreshtha *et al.*** (**2014**) devoted to the achievement and current status of mycoremediation technology based on mushroom cultivation (7 species) for the remediation of waste and also focused on the safety aspects of mushroom cultivation on waste. Thus, the analysis of publications, identification of trends and prospects of utilization of agricultural waste by higher mushrooms is relevant and important. Publications (Table) should be divided into three categories. Some researchers explored primarily yield, biological efficiency (BE) and morphological parameters of fungi. Of great interest is the analysis of the biochemical composition of the substrates and mushrooms grown on them, the definition of therapeutic activity of fungi, depending on the substrate. The use of food processing waste is separate important problem.

YIELD, BIOLOGICAL EFFICIENCY AND MORPHOLOGICAL PARAMETERS OF MUSHROOMS

Agaricus bisporus is the largest commercially produced mushroom in the world. **Ram and Kumar** (**2010**) investigated morphological parameters of *A. bisporus* fruiting bodies (initiation of pin heads, harvesting of flushes, diameter and weight of fruit bodies), total yield in cultivation on different agricultural waste. Six mixture formulations were used as substrate for studies (Table 1) Maximum weight of sporophore was obtained with application of casing coconut coir pith + vermi compost + sand, where maximum length of stalk was recorded from coconut coir pith + farm yard manure + sawdust casing mixture. The total maximum yield (1199.99 g) was obtained by the application of coconut coir pith

+ vermi compost + farm yard manure + sawdust + sand, which differs significantly.

Pleurotus species (Oyster mushrooms) is the second most cultivated edible mushroom in the world. Optimal conditions for *P. ostreatus* growth, yield, biological efficiency (BE) and mushroom size have been studied by a number of authors (**Elenwo and Okere, 2007; Pathmashini *et al.*, 2008; Kumari and Achal, 2008; Nwokoye *et al.*, 2010; Samuel and Eugene, 2012; Oseni *et al.*, 2012; Govindaraju *et al.*, 2013; Yang *et al.*, 2013; Ashrafi *et al.*, 2014; Mohammed *et al.*, 2014**). Two crops of *P. ostreatus* were grown on rice straw as the basic substrate. In crop I, rice straw was mixed at spawning with 0 %, 25 %, 50 %, 75 % and 100 % of banana leaves or *Leucaena leucocephala* or maize bran or maize cobs. In crop II, rice straw was supplemented at spawning with 0 %, 1 %, 2 %, 3 %, 4 %, and 5 % of sunflower or cotton seed cake. Mushroom yield (1,040.0 g) and BE (98.5 %) were greater on a 50/50 mixture of rice straw and banana leaves. Rice straw supplemented with 2 % sunflower seed hulls (yield =1,087.5 g, BE =103.3 %) gave similar yield and BE to rice straw supplemented with 2 % cotton seed hulls (yield =1,073.8 g, BE =101.8 %), and were significantly greater than other supplement ratios. The largest mushrooms (21.0 g) were obtained from non-supplemented rice straw (**Mamiro and Mamiro, 2011**). Three strains of *P. eryngii* such as Pe-1 (native to Bangladesh), Pe-2 (germplasm collected from China) and Pe-3 (germplasm collected from Japan) were cultivated on sawdust and rice straw and their growth and yield parameters were investigated (**Moonmoon *et al.*, 2010**). Pe-1 on sawdust showed the highest biological yield and BE (73.5 %) than other strains. Also, the mycelium run rate and number of fruiting bodies were higher in Pe-1 than other two strains. The quality of mushroom strains was near about similar. On sawdust, the yield and efficiency were better than those cultivated on rice straw, however, on straw the mushroom fruiting bodies were larger in size. *P. florida* cultivation on different substrate compositions has been investigated by **Mondal *et al.*, (2010)**. Highest mycelium running rate was found on banana leaves and rice straw (1:1) but the lowest in control. Completion of mycelium running time was lowest on banana leaves and rice straw (1:3 and 3:1). Number of total primordia and effective primordia, found highest in control but the maximum pileus thickness was measured from rice straw. Highest biological yield and economic yield (164.4 g and 151.1 g) was obtained from rice straw which was much higher than control. A number of papers devoted to the study of the process of *P. pulmonarius* cultivation on different mixtures of cotton waste and cassava peel (Adebayo et al. 2009), cotton waste alone and combined with rice husk (**Khan *et al.*, 2010**), coir fibre, oil palm waste, sawdust of *Gmelina arborea* and rice straw (**Jonathan *et al.*, 2013**). *P. pulmonarius* was also cultivated on agricultural wastes viz., cotton, rice straw, corn cob, corn husk and sawdust (S). Rice bran was added as a nutritional supplement to each substrate. Data collected after two weeks of incubation were diameter of the cap (pileus), length of stem (stipe) and dry matter of fruiting body. The dry matter (32.4±1.5 g) and pileus (19.2±2.4 cm) of fruiting bodies cultivated on cotton waste supplemented with rice bran (CR) was significantly higher while at the same level of significance, the stipe (18.0±1.2 cm) for corn husk supplemented with rice bran (CHR) has significance difference compared with other substrates. Supplemented substrates yielded better compared with non-supplemented substrates. CR was the best substrate followed by CHR while S was least. In addition to sawdust which is widely used by farmers, cotton waste, corn cob, husk and rice straw are possible agro-waste materials for *P. pulmonarius* production (**Adedokun, 2014**). **Mane *et al.*, (2007)** studied the yield and morphological parameters of *P. sajor-caju* fruiting bodies in cultivation on selected agro wastes viz. cotton stalks, groundnut haulms, soybean straw, pigeon pea stalks and leaves and wheat straw, alone or in combinations. Cotton stalks, pigeon pea stalks and wheat straw alone or in combination were found to be more suitable than groundnut haulms and soybean straw for the cultivation. Organic supplements such as groundnut oilseed cake, gram powder and rice bran not only affected growth parameters but also increased yield. Mycelial growth, colonization period, primordial initiation, harvesting time, yield, mushroom size and BE of *P. sajor-caju* were assessed on three different substrates namely maize stalk, pea residue (tendrils) and banana leaves with and without supplementation of rice bran and chicken manure. The faster mycelial growth and highest yield (348.13 g) with 87.03 % BE was obtained from maize stalk with rice bran and second best yield (299.53 g) with 74.88 % BE was recorded from pea residue with rice bran. Among the substrates used, maize stalk appeared best followed by pea residue and banana leaves. Rice bran showed best supplementation for mycelial growth and yield with all substrates (**Pokhrel *et al.*, 2013**). **Dehariya and Vyas (2013)** determined the effect of different agro-wastes viz. soybean straw, wheat straw, paddy straw, sugarcane bagasses, sun flower stalks, maize stalks, domestic waste, used tea leaves, fruit waste, semal flowers, news paper, bamboo leaves, sawdust and their combinations in 1:1 proportion in *P. sajor-caju* cultivation (yield and BE). Soybean straw showed significantly highest yield (with 93.3 % BE). Among all the combinations soybean straw + wheat straw showed significantly highest yield (with 87.3 % BE). The organic wastes (dry substrates which include maize cob, cassava peelings, plantain peelings and water melon pod) were used in the study of *P. tuber-regium* cultivation. Maize cob (T1) and cassava peelings (T2) supported very abundant mycelial growth and also the development of healthy fruit bodies of the fungus studied. Plantain peelings (T3) and water melon pod (T4) supported abundant and moderate mycelial growth of *P. tuber-regium* respectively but fruit bodies were not developed on them. In all parameters measured fruit bodies produced on T1 were better than those on T2 except in dry weight (DW). The DW of *P. tuber-regium* was 21.8 g on both T1 and T2. The BE of *P. tuber-regium* produced on T1 were 8.7 % and 8.5 % on T2. Corn cobs and cassava peelings which are major agro wastes abundantly found in Nigeria, have been found to excellently support the mycelial growth and fruit body formation of *P. tuber-regium* (**Stanley and Odu, 2012**). The powerful enzyme system of *Pleurotus* spp. promotes biodegradation of the wide spectrum of substrates, not only traditional sawdust and cereal straw (Table). The increasing interest in *Pleurotus* spp. mushrooms is explained also of their species diversity.

The influence of seven oak-wood sawdust substrates (OS), supplemented with wheat straw (WS) or corn-cobs (CC) on mycelium growth and sporophore production characteristics of *Lentinula edodes* (popular edible mushroom) was examined by **Philippoussis *et al.*, (2004)**. Colonization rate measurements demonstrated faster colonization on OS supplemented with WS or CC in a ratio of 1:2 (OS : supplements). Similarly, higher sporophore yields were obtained on OS + CC mixtures, especially in the supplementation ratios 1:1 and 1:2. However, substrates with high OS content (2:1 ratio) appeared to promote mushroom quality and high protein content of the sporophores. *L. edodes* cultivation on hard wood sawdust, rice straw, crushed corn cobs and crushed bagasse supplemented with 20 % wheat bran, 1 % soy bean flour, 2 % gypsum has been investigated by **Hassan (2011)**. Incubation period, early of harvesting, yield and BE were estimated as well as drying parameters for fruit bodies. Sawdust recorded the shortest incubation time and first harvesting day time, while bagasse showed the longest ones. Also, sawdust produced the maximum yield 297 g/ kg wet media with the highest BE, while bagasse recorded the lowest values.

Pani (2012) studied the utilization of cotton wastes and sunflower stalks either alone or in combination with paddy straw (1:3, 1:1, 3:1) for sporophore production of milky mushroom, *Calocybe indica*. The various combinations with paddy straw showed better results (BE) than single substrates (cotton wastes and sunflower stalks). There was also faster substrate colonization and primordial initiation and higher number of fruiting bodies. Cotton wastes + paddy straw (1:3) sustained the highest mushroom yield (73.2 % BE) which was statistically at par with paddy straw (71.3 % BE).

Akavia *et al.*, (2009) investigated the cultivation of five *Hypsizygus marmoreus* strains on 24 substrates (Table 1). Average number of colonized particles per day, BE, number of mushrooms and weight of mushrooms harvested during one month have been studied. The best substrate in terms of BE was corn cob with bran and olive press cake, with a BE of 85.6%. The BE of the same composition but without olive press cake was only 67.5 %.

Harvesting yield and BE of *Pholiota nameko* utilization of different substrates viz. *Eucalyptus* shaving, *Cordia* shaving, coffee husk, *Pinus* shaving, cotton seed and teff straw have been studied by **Gizaw (2010)**. Wheat bran was used as an additive material 100:10 and 100:30 w:w of the main material. *Eucalyptus* shaving supplemented with 30 % wheat bran showed the best result (yield = 797.33 g, BE = 53.27 %).

The effect of pH and temperature variations on the growth of *Volvariella volvacea* cultivated on various agricultural wastes singly and in various combinations has been studied by **Akinyele and Adetuyi (2005)**. A pH range of 5.5 to 8.5 recorded the maximum mycelia yield and the highest mycelia weight was recorded at pH 6.5. High mycelia growth of the mushroom was also observed between 25°C and 30°C with the highest mycelia DW of 80.0 mg obtained at 30°C. Effect of different substrates on mycelial growth and yield of *Volvariella* spp. (*V. diplasia* and *V. volvacea*) was also evaluated (**Tripathy *et al.*, 2011**). Paddy straw, oil palm fibre, sawdust, and a mixture of oil palm fibre and sawdust were screened for the cultivations of *V. volvacea*. The paddy straw served as the control as it is the traditional substrate for the growth of this mushroom. The straw naturally supported the mycelial growth and production of fruit bodies. Growth and production of fruit bodies on oil palm fibre was similar to that of paddy straw. The production of fruit bodies on the mixture of oil palm fibre and sawdust was scanty. Sawdust alone as a substrate produced few fruit bodies that were comparatively small in size (**Onuoha *et al.*, 2009**). *V. volvacea* showed that it is an active agro waste bio-destructor, not only the traditional for this fungus paddy straw.

Researchers are interested not only in *Pleurotus* spp. and *Volvariella* spp. fruit bodies (first of all) cultivation on cheap substrates, but also in best-known and very delicious edible mushrooms, such as *Agaricus* spp., *Lentinus* spp., *Hypsizygus marmoreus*.

Table 1 Utilization of agro-industrial waste by higher mushrooms

Fungal species	**Wastes and some non waste components (if they are basic for substrates or control in studies)**	**Best results**	**References**
Agaricus bisporus (J.E. Lange) Imbach	mung bean straw; beet pulp coconut coir pith; farm yard manure; sawdust; vermi compost (wheat straw, wheat bran, urea, potassium, phosphorus, gypsum molasses and lindane); sand rice straw; rice bran; chicken manure	mung bean straw (yield =2.56 kg/10kg) coconut coir pith +vermi compost + farm yard manure + sawdust + sand (1:1:1:1:1) ***	**(Al Abttan *et al.*, 2005)** **(Ram & Kumar, 2010)** **(Peng, 2010)**
Agaricus bitorquis (Quel.) Sacc.	rice straw; rice bran; chicken manure	***	**(Peng, 2010)**
Agaricus flocculosipes R.L. Zhao, Desjardin, J. Guinberteau & K.D. Hyde	wheat straw +horse manure	yield = 1.04 g /kg	**(Thongklang *et al.*, 2014)**
Agaricus subrufescens Peck	wheat straw +horse manure	yield = 85.90 g /kg	**(Thongklang *et al.*, 2014)**
Agrocybe aegerita (V.Brig.) Singer	wheat straw; cocoa shells; wheat straw supplemented with either cocoa shells (17 %), citrus pellets (17 %), carrot mesh (17 %) or black tea pomace (17 % and 45 %)	wheat straw supplemented with black tea pomace (17 % and 45 %). BE =36 %	**(Kleofas *et al.*, 2014)**
Agrocybe cylindracea (DC.) Maire	rice bran; wheat bran wheat straw; two-phase olive mill waste; composted two-phase olive mill waste	*** wheat straw + 20% composted two-phase olive mill waste (yield =377.91 g)	**(Peng, 2010)** **(Zervakis *et al.*, 2013)**
Antrodia cinnamomea T.T. Chang & W.N. Chou	citrus peel (pomelo, lemon, orange and grapefruit) extracts	lemon peel extract	**(Yang *et al.*, 2012)**
Auricularia auricula-judae (Bull.) Quél.	dry olive mill residue	increases peroxidase secretion and produced a sharp decrease in total phenolic content	**(Reina *et al.*, 2013)**
Auricularia fuscosuccinea (Mont.) Henn.	rice bran; wheat bran substrates alone and in combination (1: 1): coir; shells of cacao; banana leaves	*** banana leaves (mycelial growth rate = 6 mm / day)	**(Peng, 2010)** **(Carreno-Ruiz *et al.*, 2014)**
Auricularia polytricha (Mont.) Sacc.	sawdust mixed with empty fruit bunches (50:50) + 10 % spent grain; sawdust mixed with oil palm fronds (90:10) + 15 % spent grain and compared to 100 % sawdust	sawdust mixed with oil palm fronds (90:10) + 15 % spent grain – BE = 288.9 %	**(Abd Razak *et al.*, 2013)**
Auriporia aurea (Peck) Ryvarden	amaranth flour after CO_2 extraction	high antiviral activity	**(Krupodorova *et al.*, 2014b)**
Bjerkandera adusta (Willd.) P. Karst.	dry olive mill residue	increases peroxidase secretion and produced a sharp decrease in total phenolic content	**(Reina *et al.*, 2013)**
Calocybe indica Purkay. & A. Chandra	rice bran; maize powder; wheat bran supplement to rice straw ten popular paddy straw varieties of Orissa cotton wastes and sunflower stalks alone or mixed with paddy straw (1:3, 1:1, 3:1) coir pith; maize straw; paddy straw; sugarcane bagasse; sugarcane leaves and vettiver leaves sorghum straw; paddy straw; sugarcane bagasse; banana leaves paddy straw; wheat straw; soybean straw; coconut coir pith; cotton waste; sugarcane bagasse paddy straw; reeds; banana stem; sugarcane bagasse milled and crushed; sugarcane leaves; coir pith; sorghum husk; sunflower stem	30% maize powder supplement to rice straw (biological yield = 459.3 g/packet) variety: CR-1014 (70.5 % bioefficiency (BE), Kanchan (69.9 % BE), Jagabandhu (69.6 % BE) cotton wastes +paddy straw (1:3) paddy straw (protein=31.2 g/100g **,** carbohydrate = 58.4 g/100g), coir pith (fat = 0.85 g/100g), sugarcane bagasse (yield) wheat straw; paddy straw paddy straw (BE = 91.81 %)	**(Alam *et al.*, 2010)** **(Pani, 2011)** **(Pani, 2012)** **(Lakshmipathy *et al.*, 2012)** **(Ramanathan *et al.*, 2013)** **(Vijaykumar *et al.*, 2014)** **(Karuppuraj *et al.*, 2014)**
Coprinellus radians (Desm.) Vilgalys, Hopple & Jacq. Johnson	dry olive mill residue	increases peroxidase secretion and produced a sharp decrease in total phenolic content	**(Reina *et al.*, 2013)**
Coprinus comatus (O.F. Müll.) Pers.	rice bran; wheat bran spent of *P. sajor-caju*, *P.ostreatus* and *P.florida* mixed with 100 g of the different enrichment types (corn grit, rice grit and rice bran)	*** spent of *P. sajor-caju* mixed with 100 g of corn grit (yield =11.06 g)	**(Peng, 2010)** **(Dulay *et al.*, 2014)**
Flammulina velutipes (Curtis) Singer	rice bran; wheat bran paddy straw; palm empty fruit bunches; palm-pressed fiber	*** paddy straw + palm empty fruit bunches (25:75). BE = 185.09 %	**(Peng, 2010)** **(Harith *et al.*, 2014)**
Fomes badius Cooke	coffee pulp	cellulose degradation (61.3 %); hemicellulose degradation (51.2 %)	**(Parani & Eyini, 2010)**
Fomes fomentarius (L.) Fr.	amaranth flour after CO_2 extraction	high antiviral activity	**(Krupodorova *et al.*, 2014b)**

Ganoderma applanatum (Pers.) Pat.	milk whey; starch grits	milk whey	**(Krupodorova, 2011)**
Ganoderma lucidum (Curtis) P. Karst	sawdust (S) + tea waste (TW) at the various levels (75S:25TW, 80S:20TW, 85S:15TW, 90S:10TW) coffee pulp milk whey; starch grits hydrolysed rye straw – 55 %; oak sawdust – 25 %; rye bran – 10 %; corn flour - 8 %; chemically precipitated chalk – 1 %; rock gypsum – 1 %. coir pith + fishery waste (1:1); woodchips + fishery waste (1:1); sugarcane bagasse + fishery waste (1:1) sawdust and rice bran + food waste compost at the various levels	80S:20TW; 75S:25TW cellulose degradation (64.3 %); hemicellulose degradation (51.2 %) milk whey *** coir pith+ fishery waste (1:1) sawdust and rice bran + 10 % of food waste compost	**(Peksen & Yakupoglu, 2009)** **(Parani & Eyini, 2010)** **(Krupodorova, 2011)** **(Patent RU No. 2,453,105, 2012)** **(Lakshmi, 2013)** **(Jo *et al.*, 2013)**
Ganoderma tsugae Murrill	rice bran; wheat bran	***	**(Peng, 2010)**
Hericium erinaceus (Bull.) Pers.	sawdust + 20 % wheat bran + 1 % $CaCO_3$ + 1 % sugar; rice straw + 20 % wheat bran + 1 % $CaCO_3$ + 1 % sugar; wheat straw + 20 % wheat bran + 1 % $CaCO_3$ + 1 % sugar; sawdust + rice straw + 20 % wheat bran + 1 % $CaCO_3$ + 1% sugar; sawdust + wheat straw + 20 % wheat bran + 1 % $CaCO_3$ + 1 % sugar; rice straw + wheat straw + 20 % wheat bran + 1 % $CaCO_3$ + 1 % sugar rice bran; wheat bran	sawdust (yield = 184 g/kg); wheat straw (protein); sawdust + wheat straw + 20 % wheat bran + 1 % $CaCO_3$ + 1 % sugar (fat) ***	**(Hassan, 2007)** **(Peng, 2010)**
Hypsizygus marmoreus (Peck) H.E. Bigelow	corn cob; bran; olive press cake; cotton straw; crashed cotton seed; cotton waste; wheat straw; banana leaves; pea straw; mandarin peel; red wine waste; soy seed skin; hard almond shells; coffee ground; sunflower seed shells; soft almond shells; sunflower straw; coco fiber in different ratio sawdust; rice bran; wheat bran; corn flour	corn cob 60 %, bran 30 %, olive press cake 10 % ***	**(Akavia *et al.*, 2009)** **(Peng , 2010)**
Lentinus connatus Berk.	paddy straw; sorghum stalk; banana pseudostem	paddy straw	**(Rani *et al.*, 2008)**
Lentinus edodes (Berk.) Singer	Sikhae factory waste with addition of: D-fructose; D-galactose; D-glucose; sucrose; maltose; starch; D-mannose and cellulose; $MgSO_4 \cdot 7H_2O$; $ZnSO_4 \cdot 7H_2O$; KCl, NaCl; $CaCl_2$; $CuSO_4$; $FeSO_4$ oak-wood sawdust; supplemented with wheat straw or corn-cobs 50–80 % wheat straw + 20–50 % olive oil waste + 2–10 % gypsum; 50–70 % wheat straw + 30–50 % olive oil waste + 5–10 % gypsum; 50–60 % wheat straw + 30–40 % olive oil waste + 5–10% gypsum; 57% wheat straw+ 37% olive oil waste+ 6% gypsum 71-78 % hardwood sawdust + 0.1–3 % chalk+0.1-3 % gypsum + rape grain waste (the rest) rice bran; wheat bran barley straw; wheat straw; vineyard-pruning sawdust; rice straw; crushed corn cobs and crushed bagasse supplemented with 20 % wheat bran, 1 % soy bean flour, 2 % gypsum winery and apple wastes (1:1); winery wastes + wheat bran (9:1); winery wastes + rye bran (9:1); apple wastes + wheat bran (9:1); apple wastes + rye bran (9:1) apple wastes + 1.5 % barley; apple wastes + 2 % wheat bran; pear wastes + 1.5 % barley bran; plum wastes + 2.5 % barley bran; apple wastes + 3 % wheat bran oak sawdust; rice bran; beet pulp; and cottonseed hull supplemented with food waste compost at the various levels	Sikhae factory waste + 1 % sucrose + 0.05 % $MgSO_4 \cdot 7H_2O$ oak-wood sawdust + corn-cobs *** *** *** *** sawdust supplemented with 20 % wheat bran, 1 % soy bean flour, 2 % gypsum apple wastes + wheat bran (9:1) (cellulose degradation 0.7 g% d.w.) plum wastes + 2.5 % barley bran (cellulose degradation 0.7 g%) oak sawdust, rice bran, beet pulp, and cottonseed hull supplemented with 13 % of food waste compost	**(Jung *et al.*, 2001)** **(Philippoussis *et al.*, 2004)** **(U.S. Patent No.7,043,874, 2006)** **(Patent BY No.8910, 2007)** **(Peng, 2010)** **(Gaitán-Hernández *et al.*, 2011)** **(Hassan, 2011)** **(Petre & Petre, 2012)** **(Petre & Petre, 2013b)** **(Jo *et al.*, 2013)**
Lentinus giganteus Berk.	rice bran; wheat bran	***	**(Peng, 2010)**

Lentinus tigrinus (Bull.) Fr.	wheat straw (77 %), supplemented with wheat meal (20 %) and $CaCO_3$ (3 %)	BE =62 %	**(Lechner & Papinutti, 2006)**
Lyophyllum decastes (Fr.) Singer	livestock composts - one year (C-I) and five weeks (C-II), fermented with five supplements (barley bran; corn husk; a mixture of wheat, rice, barley (WRB) brans; cotton waste, and nucleic acid)	C-I with WRB bran and barley bran supplements, with BE of 59.34 % and 56.21 %, respectively	**(Pokhrel *et al.*, 2006)**
Morchella esculenta (L.) Pers.	detoxified loquat kernel extract (DLKE); neutralized loquat kernel extract (LKE); malt extract (ME) glucose (40 g/l) + yeast extract (3 g/l) + chicken feather peptone (10 g/l); glucose (40 g/l) + yeast extract (3 g/l) + tryptone peptone (10 g/l); glucose (40 g/l) + yeast extract (3 g/l) + fish peptone (10 g/l)	ME (biomass = 18.9 g/L, exopolysaccharide = 5.3 g/L), DLKE (biomass = 16.7 g/L, exopolysaccharide = 5.2 g/L) glucose + yeast extract + tryptone peptone (biomass = 16.3 g/l, extracellular polysaccharides = 4.8 g/l)	**(Taskin *et al.*, 2011)** **(Taskin *et al.*, 2012)**
Oudemansiella canarii (Jungh.) Höhn.	substrates alone and in combination (1:1): shells of cacao, banana leaves	shells of cacao (mycelial growth = 5.98 mm /day); shells of cacao + banana leaves (mycelial growth = 5.98 mm /day)	**(Carreno-Ruiz *et al.*, 2014)**
Oudemansiella tanzanica (nomen provisorum)	sawdust; sisal waste and paddy straw supplemented with rice bran or dried chicken manure	sawdust with chicken manure (5 %)	**(Magingo *et al.*, 2004)**
Phanerochaete chrysosporium Burds.	coffee pulp corn straw, rice husk; local grass powder; sugarcane leaves; sugarcane bagasse	cellulose degradation (62.1 %); hemicellulose degradation (48.7 %) grass powder (enzymes production)	**(Parani & Eyini, 2010)** **(Saratale *et al.*, 2014)**
Phellinus linteus (Berk. & M.A. Curtis) Teng	cheese-processing waste (whey)	mycelia growth rate 2.80 mm /day	**(Lee *et al.*, 2011)**
Pholiota adiposa (Batsch) P. Kumm.	oak sawdust; rice bran; beet pulp; and cottonseed hull supplemented with food waste compost at the various levels	oak sawdust, rice bran, beet pulp, and cottonseed hull supplemented with 13 % of food waste compost	**(Jo *et al.*, 2013)**
Pholiota nameko (T. Itô) S. Ito & S. Imai	*Eucalyptus* shaving; coffee husk; cotton seed and teff straw . Wheat bran was used as additive material 100:10 and 100:30 w:w of the main material	*Eucalyptus* shaving supplemented with 30 % wheat bran	**(Gizaw, 2010)**
Pleurotus citrinopileatus Singer	rice bran; wheat bran paddy straw; brassica straw; pea pod shell; cauliflower leaves and radish leaves separately and on various combinations of paddy straw and aforementioned wastes PDA (potato dextrose Agar) culture medium with aquatic extraction solution from waste material of *Auricularia auricula*	*** 70 % paddy straw and 30 % brassica straw (BE = 94.33 %), 70 % paddy straw and 30 % pea pod shell (BE = 94.33 %) PDA culture medium with 20 % aquatic extraction solution from waste material of *Auricularia auricula*	**(Peng 2010)** **(Singh & Singh, 2011)** **(Wang *et al.*, 2013)**
Pleurotus cystidiosus O.K. Mill.	rice bran; wheat bran sawdust – control; sawdust + cocoa pods waste (80%:20%; 75:25%; 70% :30%)	*** 75% sawdust+25% cocoa pods waste (BE = 64.49 %)	**(Peng, 2010)** **(Mudakir *et al.*, 2014)**
Pleurotus djamor (Rumph. ex Fr.) Boedijn	cotton waste; paddy straw; wheat straw	cotton waste (yield= 40 g)	**(Ashraf *et al.*, 2013)**
Pleurotus eous (Berk.) Sacc.	paddy straw; sorghum stalk; banana pseudostem coffee pulp soybean straw	paddy straw (BE = 55.49 %) cellulose degradation (61 %); hemicellulose degradation (53.7 %) yield = 383.81 g	**(Rani *et al.*, 2008)** **(Parani & Eyini, 2010)** **(Ingale & Ramteke, 2010)**
Pleurotus eryngii (DC.) Quel.	wheat straw (WS); cotton straw (CS); lentil straw (LS) and rice bran (RB) rice bran; wheat bran wheat straw; raw two-phase olive mill waste; composted two-phase olive mill waste 15 % cotton seed + 20 % sawdust + 45 % crushed corn + 17 % bran +1 % slaked lime +1 % gypsum powder + 1 % sugar	WS-CS (1:1) + 20 % RB (yield = 23.2 g/100 g) *** wheat straw + 40 % composted two-phase olive mill waste (yield = 363.69 g) ***	**(Kirbag & Akyuz, 2008)** **(Peng, 2010)** **(Zervakis *et al.*, 2013)** **(Patent KZ No.28780, 2014)**
Pleurotus flabellatus Sacc.	coffee pulp sugarcane baggase + cooked fish waste (head, tail, shells, fins, intestine, dead fishes and so on) = 1:1; coir pith + cooked fish waste; woodchips + cooked fish waste	cellulose degradation (54.4 %); hemicellulose degradation (46.8 %) sugarcane baggase + cooked fish waste	**(Parani & Eyini, 2010)** **(Lakshmi & Sornaraj, 2014)**
Pleurotus floridanus Singer	corn cob; corn husk; and poultry waste (used as an additive) sugarcane leaves; sugarcane bagasse; coir; rice straw; cotton waste; banana leaves cotton waste and paddy straw with supplementation	corn husk (BE = 0.36 %, mean mushroom weight = 45 g) banana leaves (protein and lipids), cotton waste (lipids) cotton waste with + wheat bran (yield =	**(Elenwo & Okere, 2007)** **(Khan *et al.*, 2008)** **(Narayanasamy *et al.*, 2008)**

	of wheat bran coffee cherry husk; coffee parchment husk; coffee silver skin; coffee spent wastes; coffee dried leaves with and without supplementation of agricultural wastes such as wheat bran soybean straw; paddy straw; wheat straw and their combination in 1:1 proportion banana leaves and rice straw alone or mixed (1:3; 1:1; 3:1) soybean straw wheat straw; barley straw; maize stem residue and lawn residue with supplementation of wheat bran and rice bran sorghum straw; paddy straw; sugarcane bagasse; banana leaves elephant grass; cotton seed husks; sugarcane bagasse; corn cobs; beans straw; mixtures (1:1): bagasse + maize cobs; bagasse + beans straw paddy straw; reeds; banana stem; sugarcane bagasse milled and crushed; sugarcane leaves; coir pith; sorghum husk; sunflower stem SMS (spent mushroom substrate); sawdust; wheat bran in different compositions	74.35 g) coffee parchment husk + coffee cherry husk + coffee silver skin + coffee spent wastes + coffee dried leaves + wheat bran (20 % : 20 % : 20 % : 20 % : 10 % : 10 %) soybean straw (total yield = 875.66 g/kg, BE = 87.56 %) rice straw; banana leaves : rice straw = 1:3 yield = 283.21 g wheat straw + rice bran (yield = 1039.00 g per 500g substrate dry weight; BE = 207.8 %) paddy straw (yield) cotton seed husks (yield = 118 kg) sorghum husk (BE = 80.35 %), paddy straw (BE = 70.23 %) SMS + sawdust + wheat bran (20 : 60 : 20) – BE = 92.7 %	**(Murthy & Manonmani, 2008)** **(Ahmed *et al.*, 2009)** **(Mondal *et al.*, 2010)** **(Ingale & Ramteke, 2010)** **(Jafarpour *et al.*, 2011)** **(Ramanathan *et al.*, 2013)** **(Ng'etich *et al.*, 2013)** **(Karuppuraj *et al.*, 2014)** **(Ashrafi *et al.*, 2014)**
Pleurotus nebrodensis (Inzenga) Quél.	62 % cotton seed +10% bran + 25 % crushed corn + 1 % slaked lime + 1 % gypsum powder + 1% 3Ca $(H_2P0_4)_2$	***	**(Patent KZ No.28781, 2014)**
Pleurotus ostreatus (Jacq.) P. Kumm.	paddy and wheat straw (in the ratio of 1 : 1), bamboo leaves and lawn grasses food wastes extracts with concentrations 10, 20, 30, 40, 50 % corn cob; cotton waste; banana leaves; elephant grass 100 – 20 % hemp shive + 0 – 80 % cereal straw; rice straw with banana leaves or *Leucaena leucocephala* or maize bran or maize cobs; rice straw with sunflower or cotton seed hulls olive mill waste water mixed with garlic and maize wastes fermented pine sawdust substrate with different levels of wheat bran corn cobs; palm cones different combinations of wastes (leaf, pseudo-stem and pseudo-stem + leaf) and banana cultivars - *Musa* spp. winery and apple wastes (1:1); winery wastes + wheat bran (9:1); winery wastes + rye bran (9:1); apple wastes + wheat bran (9:1); apple wastes + rye bran (9:1) cotton waste and rice straw with rice bran additive at varying percentage rice straw; rice straw + wheat straw; sugarcane bagasse; sawdust supplemented with 10 % rice bran (except rice straw) apple wastes + 1.5 % barley; apple wastes + 2 % wheat bran; pear wastes + 1.5 % barley bran; plum wastes + 2.5 % barley bran; apple wastes + 3 % wheat bran cotton waste; paddy straw; wheat straw	wheat straw; paddy and wheat straw (in the ratio of 1: 1) food wastes extract with concentrations 30 % corn cob (mycelial extension = 67 cm) *** rice straw + 2 % sunflower seed hulls; rice straw + 2 % cotton seed hulls olive mill waste water (15 %) + maize wastes pine sawdust + 15 % wheat bran (BE = 136.8 %) corn cobs (yield = 146.1 g) pseudo-stem waste + banana cultivar Thap Maeo (BE = 61.5 %) winery + apple wastes (1:1) (cellulose degradation 0.9 g%) cotton waste (BE = 93.6 %), cotton waste + 5 % rice bran (BE = 93.0 %) rice straw (control); rice straw + wheat straw apple wastes + 1.5 % barley (cellulose degradation 0.9 g% d.w.) cotton waste (yield = 49 g) PDA culture medium with 60 % aquatic extraction solution from waste material of *Auricularia auricular*	**(Kumari & Achal, 2008)** **(Lim *et al.*, 2009)** **(Nwokoye *et al.*, 2010)** **(Patent WO No. 2,011,145,961, 2011)** **(Mamiro & Mamiro, 2011)** **(Lechner & Monaldi, 2011)** **(Oseni *et al.*, 2012)** **(Samuel & Eugene, 2012)** **(Carvalho *et al.*, 2012)** **(Petre & Petre, 2012)** **(Jonathan *et al.*, 2012)** **(Sharma *et al.*, 2013)** **(Petre & Petre, 2013b)** **(Ashraf *et al.*, 2013)** **(Wang *et al.*, 2013)**

	PDA (potato dextrose Agar) culture medium with aquatic extraction solution from waste material of *Auricularia auricula* paddy straw; sugarcane bagasse; coconut sawdust; banana leaves cotton seed hull, wheat bran, rice straw, wheat straw in differrent proportions solid olive mill wastes + wheat straw + $CaCO_3$ sisal leaf waste: soaked in cold water, boiling in water, lime pretreatment, fermentation, co-substrate *Panicum coloratum* wheat straw; two-phase olive mill waste; composted two-phase olive mill waste wheat germ oil meal; rapeseed meal; CO_2-extraction waste – amaranth flour SMS (spent mushroom substrate); sawdust; wheat bran in different compositions *Agave salmiana* bagasse; *Agave weberi* bagasse coffee husk; cow dung; poultry manure; bone meal in different compositions tea leaves after hot water extraction + cotton seed hull	paddy straw (yield = 611.00 g); sugarcane bagasse (yield = 348 g) cotton seed hull 80 % + wheat bran 20 % solid olive mill wastes +10% wheat straw + 2% of $CaCO_3$ sisal leaf waste, co-substrate *Panicum coloratum* (1:1) – yield =164.2 g/kg wheat straw + 20 % composted two-phase olive mill waste (yield =410.09 g) wheat germ oil meal (biomass = 24.1 g/l, BE= 44.6 %); amaranth flour (biomass = 22.5 g/l, BE = 42.0 %) SMS + sawdust + wheat bran (20 : 60 : 20); SMS + sawdust (40 : 60) *Agave salmiana* bagasse coffee husk + cow dung (75 %: 25 %) – yield = 192.3 g , BE = 21.37 % tea leaves after hot water extraction (40 % –60 %) + cotton seed hull	**(Govindaraju *et al.*, 2013)** **(Yang *et al.*, 2013)** **(Mansour–Benamar *et al.*, 2013)** **(Muthangya *et al.*, 2013)** **(Zervakis *et al.*, 2013)** **(Krupodorova *et al.*, 2014)** **(Ashrafi *et al.*, 2014)** **(Heredia-Solis *et al.*, 2014)** **(Mohammed *et al.*, 2014)** **(Yang *et al.*, 2015)**
Pleurotus pulmonarius (Fr.) Quél.	different mixtures of cotton waste and cassava peel corn cob substrate supplemented with rice bran coir fibre; oil palm waste; rice straw wheat straw; two-phase olive mill waste; composted two-phase olive mill waste cotton waste; rice straw; corn cob; corn husk and sawdust with supplemented rice bran to each substrate	cotton waste (yield = 79.4 g) un-supplemented corn cob (fresh weight of fruiting bodies = 53.2 g) rice straw (yield) wheat straw + 20 % composted two-phase olive mill waste (yield = 382.16 g) cotton waste + rice bran (dry matter = 32.4 g; pileus = 19.2 cm); corn husk + rice bran (stipe = 18.0 cm)	**(Adebayo *et al.*, 2009)** **(Stanley *et al.*, 2011)** **(Jonathan *et al.*, 2013)** **(Zervakis *et al.*, 2013)** **(Adedokun, 2014)**
Pleurotus sajor-caju (Fr.) Singer	waterhyacinth (*Eichhornia crassipes*) at ratios of 25, 50 and 75 % + paddy straw cotton stalks; groundnut haulms; soybean straw; pigeon pea stalks and leaves and wheat straw, alone or in combinations; groundnut oil seed cake; rice bran; gram powder rice straw, rice straw + oilseed rape straw (75:25, 50:50, and 25:75), and oilseed rape straw alone rice bran; wheat bran soybean straw soybean straw; paddy straw; wheat straw; groundnut straw; sunflower stalk; pigeon pea stalk maize stalk; pea residue (tendrils) and banana leaves with and without supplementation of rice bran and chicken manure cotton waste; paddy straw; wheat straw soybean straw; wheat straw; paddy straw; sugarcane bagasses; sun flower stalks; maize stalks; used tea leaves; fruit waste; semal flowers; bamboo leaves (alone and in combinations in 1:1)	paddy straw + 25 % waterhyacinth (BE = 85 %) cotton stalks + pigeon pea stalks and leaves + wheat straw + groundnut oil seed cake (yield = 914.03 g/kg) rice straw + oilseed rape straw (25:75) – yield = 960.15 g/kg dry substrate) *** yield = 303.63 g soybean straw maize stalk with rice bran paddy straw (yield = 40 g) soybean straw (yield = 933.4 g/kg); soybean straw + wheat straw (yield = 873.4 g/kg) *P. angolensis* sawdust + 15 % wheat chaff (yield of 31.22 g; BE= 37.39 %); *P. angolensis* sawdust (protein of 26.33 %)	**(Nageswaran *et al.*, 2003)** **(Mane *et al.*, 2007)** **(Norouzi *et al.*, 2008)** **(Peng, 2010)** **(Ingale & Ramteke, 2010)** **(Patil, 2012)** **(Pokhrel *et al.*, 2013)** **(Ashraf *et al.*, 2013)** **(Dehariya &Vyas, 2013)** **(Fakoya *et al.*, 2014)**

	Pycnanthus angolensis sawdust supplemented with 0, 5, 10, 15, and 20 % palmkernel cake, oil palmfibre, rice bran, wheat chaff , and corn cobs		
Pleurotus sapidus Sacc.	sisal leaf waste: soaked in cold water, boiling in water, lime pretreatment, fermentation; co-substrate *Panicum coloratum*	sisal leaf waste, co-substrate *Panicum coloratum* (1:1) – yield = 156.4 g/kg	**(Muthangya *et al.*, 2013)**
Pleurotus tuber-regium (Fr.) Singer	corn cob; corn husk; poultry waste (used as an additive) fermented sawdust; oil palm fruit fibre; mixtures (1:1): oil palm fruit fibre+fermented sawdust; corn waste+ fermented sawdust; millet waste +fermented sawdust maize cob; cassava peelings; plantain peelings; watermelon pod	corn cob (BE = 0.67 %, mean mushroom weight = 118.9 g) corn waste + fermented sawdust; millet waste + fermented sawdust maize cobs (yield = 28 g); cassava peelings (yield = 28 g)	**(Elenwo & Okere, 2007)** **(Olufokunbi & Chiejina, 2010)** **(Stanley & Odu, 2012)**
Schizophyllum commune Fr.	coconut water breadcrumb sunflower seed hull without and with supplementation with either wheat bran (3.75%, 7.5 %) or 1 % vegetal oils substrates alone and in combination (1:1): coir, shells of cacao, banana leaves	coconut water (production of schizophyllan at 7.71g/1000 ml) mycelial mass = 23.96 g/l sunflower seed hull with supplementation of 7.5 % wheat bran (BE = 48.3 %) coir+ shells of cacao (mycelial growth = 9.99 mm /day)	**(Reyes *et al.*, 2009)** **(Ivanova *et al.*, 2014)** **(Figlas *et al.*, 2014)** **(Carreno-Ruiz *et al.*, 2014)**
Trametes versicolor (L.) Lloyd	rice bran; wheat bran breadcrumb amaranth flour after CO_2-extraction	*** mycelial mass = 15.76 g/l high antiviral activity	**(Peng, 2010)** **(Ivanova *et al.*, 2014)** **(Krupodorova *et al.*, 2014b)**
Volvariella diplasia (Berk. & Broome) Singer	rice bran, wheat bran, rice straw, banana leaf, sugarcane bagasse supplemented with wheat	50 % rice bran with 50 % wheat (BE = 12.43 %)	**(Tripathy *et al.*, 2011)**
Volvariella volvacea (Bull.) Singer	rice husk; rice straw; cotton waste; groundnut shell; cassava peel; corn cob; oil palm pericarp; red sorghum shaft and their blends (ratio 1:1) corn cob; corn husk; poultry waste (used as an additive) oil palm fibre; paddy straw (control) palm fiber; rice husk cotton waste; rice straw rice bran; wheat bran; rice straw; banana leaf; sugarcane bagasse mixed with wheat paddy straw; cotton waste; banana leaves; corn stovers; sugarcane baggasse and pulses straw plantain leaves; maize husk; cotton waste	cotton waste + rice husk (mycelia extension 101.87 mm) ; oil palm pericarp + groundnut shell (mycelia extension 100.67 mm) corn husk (BE = 0.09 %, mean mushroom weight = 16 g) oil palm fibre (yield = 16.3 g) palm fiber (stipe height= 4.0 cm); rice husk (pileus diameter = 4.0 cm) *** 50 % rice bran with 50 % wheat (BE = 13.6 %) cotton waste (protein = 20.0 %) maize husk (yield = 24.67 g; carbohydrate, protein, lipids, ash and fiber)	**(Akinyele & Adetuyi, 2005)** **(Elenwo & Okere, 2007)** **(Onuoha *et al.*, 2009)** **(Ukoima *et al.*, 2009)** **(Peng, 2010)** **(Tripathy *et al.*, 2011)** **(Ul Haq *et al.*, 2011)** **(Adedokun & Akuma, 2013)**

* The substrate names are in accordance with those in the cited publications
** The quantitative measure of the yield is according to the cited publication, although its dimensions were different (g; g/kg of substrate, g/100 g of substrate, g/l; etc.)
*** The statement of the fact of cultivation, without comparing the results

THE STUDY OF CULTIVATION, PHYSICOCHEMICAL, BIOCHEMICAL PARAMETERS OF SUBSTRATES AND MUSHROOMS AND THEIR BIOLOGICAL ACTIVITY

Al Abttan *et al.*, (**2005**) studied chemical composition (moisture, carbohydrates, total nitrogen, C/N, crude fibers, ether extract, ash) of substrates for *A. bisporus* cultivation. Three wastes (peas, broad bean, beet pulp) were used in different levels with mung bean straw to prepare mushroom growth media. Results indicated that mung bean straw is the best substrate, it is possible to be mixed, but it should not be more than 50 % of the composition of the growth medium which is prepared by mixing with wheat at different levels.

Nutritional values of *P. ostreatus* cultivated on different agricultural wastes studied by a number of authors (**Jonathan *et al.*, 2012; Aguilar-Rivera *et al.*, 2012; Bermudez-Savon *et al.*, 2014; Alananbeh *et al.*, 2014**), as well as pH and chemical composition of the substrates also (**Amuneke *et al.*, 2011; Carvalho *et al.*, 2012; Aguilar-Rivera *et al.*, 2012; Bermudez-Savon *et al.*, 2014; Alananbeh *et al.*, 2014**). Total ash, fibre, protein, fat, carbohydrate and energy of *P. ostreatus* grown on different substrates as well as yield, size and BE have been investigated by **Sharma *et al.***, (**2013**). All the substrates (rice straw + wheat straw, rice straw + paper, sugarcane bagasse and sawdust of alder) except rice straw were supplemented with 10 % rice bran. The substrate without supplement was considered as control. Among all aspects, rice straw (control) was found as a best substrate with yield (381.85 g) and BE (95.46 %) followed by rice + wheat straw, rice straw + paper waste for the production of mushroom. The nutritional composition was also better from mushroom fruit grown on rice straw. **Kumari and Achal** (**2008**) studied the effect of paddy straw, wheat straw, mixture of paddy and wheat straw (in the ratio of 1:1), bamboo leaves and lawn grasses on the production of *P. ostreatus*. Wheat straw and a mixture of paddy and wheat straw gave the earliest colonization of fungus. The highest yield was recorded on wheat straw (29.27 g fresh weight/Kg substrate), followed by the combination of paddy and wheat straw (27.96 g/Kg). Non-enzymatic antioxidant activities were also obtained by estimating vitamins A, C and E. Significant amount of vitamin E was found in both fresh (7.23 mg/g) and dry fruit body (5.93

mg/g) of *P. ostreatus*. The effect of autoclaved sterilized and non-sterilized substrate on growth and yield of oyster mushroom was examined by **Yang *et al.*,** (**2013**). *P. ostreatus* was cultivated on rice straw basal substrate, wheat straw basal substrate, cotton seed hull basal substrate, and wheat straw or rice straw supplemented with different proportions (15 %, 30 %, and 45 % in rice straw substrate, 20 %, 30 %, and 40 % in wheat straw substrate) of cotton seed hull. The non-sterilized substrate did not gave significantly higher mushroom yield and BE than the sterilized substrate, but some undesirable characteristics, i.e. smaller mushroom cap diameter and relatively long stipe length. Growth, yield, and proximate composition (fat, fibre, ash, protein, carbohydrate) of *P. sajor-caju* cultivated on *Pycnanthus angolensis* sawdust supplemented with 0, 5, 10, 15, and 20 % palm kernel cake, oil palm fibre, rice bran, wheat chaff, and corn cobs have been studied by **Fakoya *et al.*,** (**2014**). *P. sajor-caju* produced maximum yield of 31.22 g on sawdust supplemented with 15 % wheat chaff. The BE ranged from 6.09 % to 37.39 %. Results also showed a maximum crude protein of 26.33% of *P. sajor-caju* cultivated on sawdust without any supplement and fat content ranging from 0.25 % to 2.21 %. Fibre content of harvested mushrooms ranged from 5.05 % to 9.29 %. Effect of different substrates on nutritional content of *P. sajor-caju* has been stadied by Patil (2012). *P. sajor-caju* was cultivated on soybean straw, paddy straw, wheat straw, groundnut straw, sunflower stalk and pigeon pea stalk. Soybean straw showed significantly highest yield (845.66 g/kg) and BE with maximum crude protein (25.33 %) content. Significantly maximum moisture and crude fiber content was recorded on sunflower stalk, i.e. 89.35 % and 7.82 % respectively. Maximum total carbohydrate (56.00 %) was recorded on wheat straw, while maximum fat and ash content of *P. sajor-caju* was recorded on groundnut straw, i.e. 2.85 % and 7.00 % respectively. **Ashraf *et al.*,** (**2013**) studied growth and yield, morphological parameters, chemical composition of three varieties of Oyster mushroom (*P. sajor-caju*, *P. ostreatus*, and *P. djamor*) grown on three different substrates cotton waste, wheat straw and paddy straw. The fastest spawn running, primordial initiation, harvesting stage, maximum number of fruiting bodies and maximum yield was observed on cotton waste. *P. djamor* showed the highest percentage of dry matter (17.23 %) and moisture content was found high in *P. sajor-caju* (87.37 %). *P. ostreatus* and *P. sajor-caju* showed the maximum protein (27.23 %) and fiber (26.28 %) contents. The ash contents were found maximum in *P. sajor-caju* (9.08 %). The highest fat and carbohydrate contents were found in *P. djamor* (3.07 % and 37.69 % respectively). *P. citrinopileatus* protein, total sugar and non reducing sugar content have been investigated in process of cultivation on paddy straw, brassica straw, pea pod shell, cauliflower leaves and radish leaves separately and on various combinations of paddy straw and aforementioned wastes (**Singh and Singh, 2011**). The mushroom failed to grow on pea pod shell, cauliflower leaves and radish leaves when it was cultivated separately on these vegetable wastes. However, it grew very well on paddy straw in combination with other substrates. 70 % paddy straw and 30 % other wastes combination supported maximum BE of mushroom followed by 80 % paddy straw and 20 % other wastes combination. The protein content, total sugar and non reducing sugar content was found to be higher in the mushrooms grown on paddy straw and other agro wastes combination than on paddy straw alone. Similarly, six essential amino acids i.e. leucine, isoleucine, valine, threonine, methionine and phenylalanine content was higher in the mushrooms cultivated on paddy straw and other agro wastes combination than on paddy straw alone. Nutritional composition of *P. florida* cultivated on sawdust, sugarcane leaves, sugarcane bagasse, coir, rice straw, cotton waste, banana leaves has been studied by **Khan *et al.*,** (**2008**). The amount of protein found in mushroom cultivated in banana leaves was significantly higher than in any other substrate. *P. florida* was also cultivated on soybean straw, paddy straw, wheat straw and their combination in 1:1 proportion to determine the effect of these agro waste on yield, moisture content, crude protein, total carbohydrates, fat, crude fiber, ash and minerals like Ca, P, Fe content. Soybean straw showed significantly highest yield (875.66 g/Kg), BE (87.56 %) with maximum crude protein (23.50 %) and maximum phosphorus (920 mg/100 mg of dry mushroom) content. Maximum moisture (92.45 %) and crude fiber content (8.10 %) in the fruiting bodies was recorded on paddy straw cultivation. The combination of soybean straw + paddy straw showed significantly highest fat (2.60 %), calcium (310 mg/ 100gm) and iron (13.06 mg/100gm of dry mushroom) content (**Ahmed *et al.*, 2009**). **Jonathan *et al.*,** (**2013**) reported about the yield, mineral elements content and morphological parameters of *P. pulmonarius* cultivated on coir fibre, oil palm waste, sawdust of *Gmelina arborea* and rice straw at different rice bran level. The most abundant mineral element in *P. pulmonarius* was K (30.20 mg/100 g). This was obtained on rice straw at rice bran 10 % concentration; while the least mineral element was Cu (0.006 mg/100 g). The highest values of Ca and Mg obtained were 3.90 and 2.67 mg/100 g respectively on sawdust (rice bran 10 %) and palm wastes (rice bran 20 %). The values of Fe obtained, varies from 0.007 to 0.12 mg/g on rice straw (rice bran 10 % and 40 %). Manganese has values varying from 0.04 mg/g to 0.09 mg/g on coir fibre and oil palm waste with 40 % rice bran. Highest mean stipe length (6.68 cm) was found in *P. pulmonarius* produced from rice straw while the least mean stipe length (4.08 cm) was detected on oil palm waste. The highest pileus diameter (7.08 cm) was found on rice straw while the mean height obtained from the four substrates, were relatively close with values varying between 6.0 and 9.3 cm. Rice straw produced the highest yield with total mean weight of 93.33 g. Seven different substrates supplemented with fermented sawdust were used to produce mushrooms and sclerotia of *P. tuber-regium* (**Olufokunbi and Chiejina, 2010**). Protein content ranged from 20.59 % for fermented sawdust substrate to 25.19 % for river sand substrate. The rate of substrate colonization had a significant effect on sclerotium production. The mean dry weight yields varied from 46.26 g for mixture of rice bran and fermented sawdust substrate to 127.48 g for fermented sawdust substrate alone. The highest sclerotial protein content (8.40 %) was from mixture of rice bran and fermented sawdust substrate although it was not significantly different from those of other substrates. A mixture of river sand and fermented sawdust substrate is recommended as the best substrate for the production of *P. tuber-regium* mushrooms while a mixture of corn waste and fermented sawdust substrate is recommended for sclerotial production.

The degradation of lignocellulosic wastes such as paddy straw, sorghum stalk, and banana pseudostem was investigated during solid-state fermentation by edible mushrooms *L. connatus* and *P. eous* (**Rani *et al.*, 2008**). BE of 68.75 % was observed in paddy straw followed by sorghum stalk (46.67 %) for *L. connatus* and 55.49 was observed in paddy straw followed by sorghum stalk (45.10 %) for *P. eous*. The activity of extracellular enzymes, namely cellulase, polyphenol oxidase, and laccase, together with the content of cellulose, lignin, and phenols, was studied in spent substrates on seventh, 7th, 17th, and 27th days of spawning, and these values were used as indicators of the extent of lignocellulosic degradation by mushroom. Both the mushroom species proved to be efficient degraders of lignocellulosic biomass of paddy straw and sorghum stalk, and the extent of cellulose degradation was 63–72 % of dry weight (DW), and lignin degradation was 23–30 % of the DW. The chemical changes in barley-straw (BS), wheat-straw (WS) and vineyard-pruning (VP) substrates were determined during colonization of *L. edodes* mycelia in solid state fermentation (**Gaitán-Hernández *et al.*, 2011**). VP appeared to promote early sporophore initiation. The concentration of hemicellulose in BS and VP decreased gradually from 25.5 % to 15.6 % and from 15.8 % to 12.3 %, respectively. However in WS, hemicellulose decreased from 27.2% to 9.5%. Lignin broke down continuously in BS and WS, with 31.8 % and 34.4 % degradation, respectively; higher than that of cellulose. During the pinning stage, the C:N ratio decreased in VP and BS, but not in WS. On all substrates the phenols decreased notably throughout the first week of mycelial growth. The time elapsed (days) to pinning was positively correlated with cellulose content, total sugar and inversely correlated to lignin and phenol content.

Yield, biological efficiency (BE) and the chemical composition of substrates and fruiting bodies have been investigated in *Ganoderma lucidum* solid-state fermentation on substrate mixtures with tea waste (TW) supplement (**Peksen and Yakupoglu, 2009**).

The edible mushroom *Oudemansiella tanzanica*, which is new to science, has been studied as a potential crop to reduce agricultural solid wastes and increase mushroom production. The substrates sawdust (natural for this mushroom), sisal waste and paddy straw supplemented with chicken manure resulted in the highest biological efficiencies of any mushroom cultivated in Tanzania so far. Composition of the substrates and supplements in terms of acid detergent fiber, neutral detergent fiber, lignin, cellulose, hemicellulose, carbon, C:N ratio, nitrogen, crude protein, total solids, volatile solids, pH and crude fiber, reduction in the components lignin, cellulose, hemicellulose, carbon, nitrogen, crude protein, total solids and volatile solids on studied substrates supplemented with rice bran or chicken manure after growth *of Oudemansiella tanzanica* have been investigated (**Magingo *et al.*, 2004**).

Considerable interest of researchers is the study of substrates and mushrooms chemical composition in case of *V. volvacea* cultivation. **Akinyele and Adetuyi** (**2005**) investigated the effect of pH and temperature variations on the growth of *V. volvacea* cultivated on rice husk, rice straw, cotton waste, groundnut shell, cassava peel, corn cob, white afra dust, red afra dust, oil palm pericarp and red sorghum shaft and their blends (ratio 1:1). Nutritional properties of *V. volvacea* grown on plantain leaves, maize husk and waste cotton were studied by **Adedokun and Akuma** (**2013**). Biochemical analysis of paddy straw, cotton waste, banana leaves, corn stovers, sugarcane baggasse and pulses straw used as substrates was conducted before and after inoculation with the of *V. volvacea* (strain *Vv pk*). The nitrogen %age, crude protein, crude fiber and ash contents were estimated in all substrates used for the cultivation of edible fungus, to make the comparison that how much this edible fungus plays role in the enhancement of these estimated contents in all the above mentioned substrates before and after treatment with *V. volvacea* culture. The mean values of the nitrogen percentage of the substrates showed that it was high in the cotton waste (3.80) followed by the pulses straw, paddy straw and sugarcane baggasse and minimum nitrogen was found in the banana leaves. The mean values of the protein percentage of the substrates showed that highest protein was present in the cotton waste (20.00 %) followed by the corn stover (10.28 %). The highest crude fiber was found in cotton waste (42.36 %), followed by the sugarcane baggasse (39.49 %). The ash contents were high in cotton waste (22.30 %) followed by the paddy straw (20.20 %) (**Ul Haq *et al.*, 2011**).

Only a few papers contain a study of heavy metals content in cultivated mushrooms: Pb (less than acceptable weekly intakes for adults) (**Alananbeh *et al.*, 2014**), Cd and Pb (the concentrations were under the detection limit of the metod used) (**Akyüz and Kirbağ, 2010a; Akyüz and Kirbağ, 2010b**), Cd and Pb (the concentrations of Cd were under the detection limit of the metod used, the concentrations of Pb were less than acceptable weekly intakes for adults) (**Mallikarjuna *et al.*, 2013**). At the same time, the study of wild mushrooms testify to the exceeding of permissible concentrations of heavy metals (**Falandysz *et al.*, 2001; Isiloğlu *et al.*, 2001**).

Not sufficiently studied remains the question about the effect of substrate on biological activity of fungi. Antibacterial activity of *L. edodes* against *Bacillus subtilis* was evaluated in cell-free filtrates obtained after growth in 14 different culture media. The highest *B. subtilis* growth inhibition was promoted by filtrates of growth media supplemented with rice bran, vermiculite or molasses. Antibacterial activity, detected between 20 and 24 days of incubation of stationary cultures, was absent in filtrates of aerated cultures. Temperatures of 20–25°C enhanced both growth and antibacterial activity. Optimum pH for *L. edodes* mycelial growth was 3.0–3.5, while for production of antibacterial substance – 4.5. The results indicated that incubation conditions that enhance mycelial growth are quite different from those necessary for production of antibacterial substance(s) by *L. edodes* (**Hassegawa *et al.*, 2005**). **Ramanathan *et al.*, (2013**) studied the antimicrobial activity of ethanol extracts of *P. florida* and *C. indica* cultivated on paddy straw, sugarcane bagasse, sorghum straw and banana leaf. *P. florida and C. indica* possessed antimicrobial property against antibiotic resistant human pathogens similar to that of the commercially available antibiotics. Antiviral activity against type A influenza virus of birds A/chicken/Kurgan/05/2005 (H5N1) and humans A/Aichi/2/68 (H3N2) was investigated (**Teplyakova *et al.*, 2012**) for aqueous extracts from mycelium of 11 basidial fungi species collected in the Altai Mountains (Altai Republic, Russia). A non-standard substrate (oat-corn water) was used in this study. Higher mushrooms mycelia cultivated on amaranth flour after CO_2 extraction (plant waste) have been investigated for antiviral activity *in vitro* (**Krupodorova *et al.*, 2014b**). All 10 investigated mushroom species inhibited the reproduction of influenza virus strain A/FM/1/47 (H1N1) in MDCK cells reducing the infectious titer by 2.0–6.0 lg ID50. Four species, *P. ostreatus*, *Fomes fomentarius*, *Auriporia aurea*, and *Trametes versicolor*, were also determined to be effective against HSV-2 strain BH in RK-13 cells, with similar levels of inhibition as for influenza.

The half of fungi species from 52 species represented in this review were described as bio-destructors in the last 12 years. Of them, 14 are edible and conditionally edible (*Agaricus flocculosipes*, *Agaricus subrufescens*, *Agrocybe cylindracea*, *Auricularia fuscosuccinea*, *Lentinus connatus*, *Lentinus giganteus*, *Lentinus tigrinus*, *Lyophyllum decastes*, *Oudemansiella canarii*, *Oudemansiella tanzanica*, *Pleurotus djamor*, *Pleurotus nebrodensis*, *Pleurotus tuber-regium*, *Volvariella diplasia*), and 7 – medicinal (*Antrodia cinnamomea*, *Auriporia aurea*, *Fomes fomentarius*, *Ganoderma applanatum*, *Ganoderma tsugae*, *Phellinus linteus*, *Trametes versicolor*).

One of the most important aspects of mushroom cultivation is the rational choice of the substrate. Various substrates and basic compositions were investigated and evaluated in many countries. It is obvious that the investigated substrates affected differently on mycelial growth and fructification, depending on the content of those or other nutrients in substrates and individual requirements of studied species or strains of fungi in nutrients. Some types of agro waste are characteristic for all continents of the Earth: cereal straw, cereal bran, corn, rape, rye, soy, sorghum and sunflower wastes, spent mushroom substrate, farm yard manure, chicken manure, livestock composts, vermi compost. Other wastes are characteristic of the respective continent and region of the world. To find new type of waste as a component of substrate is very difficult, therefore, the subject of the most studies mentioned in this review became different combinations of known components of substrates. Some new substrates will be discussed below.

The noticeable effect on the increase in mushroom production is explained by the development of the simple techniques of cultivation in the controlled conditions.

UTILIZATION OF FOOD WASTES (MAINLY, AFTER FOOD PROSESSING)

Food lost or wasted at the stage of processing is (by Region, 2009): North America and Oceania − 9 % (from total lost or wasted food 42 %), Industrialized Asia − 2 % (from total lost or wasted food 25 %), Europe − 5 % (from total lost or wasted food 22 %), North Africa, West and Central Asia − 4 % (from total lost or wasted food 19 %), Latin America − 6 % (from total lost or wasted food 15 %), South and Southeast Asia 4 % (from total lost or wasted food 17 %), Sub-Saharan Africa − 7 % (from total lost or wasted food 23 %) (**Lipinski *et al.*, 2013**). Significant interest of scientists focused on the ways of food processing waste management.

Sugarcane is the world's largest crop by production quantity. The worldwide harvest is more than 1.8 billion tons. For each 10 tons of sugarcane crushed, a sugar factory produces, after juice extraction, nearly 3 tons of wet bagasse. The high moisture content of bagasse, typically 40 to 50 %, is detrimental to its use as a fuel. Due to its typical (on a washed and dried basis) chemical composition (cellulose = 45–55 %; hemicellulose = 20–25 %; lignin = 18–24 %; ash = 1–4 %; waxes <1%) bagasse is of interest as a substrate for mushroom cultivation. Sugarcane baggase and six others agricultural wastes (saw dust, coir, sugarcane leaves, cotton waste, banana leaves and rice straw) were used as substrates or nutrient source for the production of *P. florida* to investigate the nutritional composition of mushroom. The protein content of *P. florida* cultivated on sugarcane baggase was one of the lowest. The amount of protein found in mushrooms cultivated in banana leaves was significantly higher than in any other substrate (**Khan *et al.*, 2008**). Elephant grass, cotton seed husks, sugarcane bagasse, corn cobs, beans straw, mixture of bagasse + maize cobs (1:1) and bagasse + beans straw (1:1) have been investigated for *P. florida* cultivation. The cotton seed husks had the greatest influence on both growth and total yield of 118 kg. It demonstrated excellent mycelia growth, greater height, stem circumference and cap diameter. The total yield on bagasse + beans straw (1:1) was the second and bagasse – the third (**Ng'etich *et al.*, 2013**). The BE of *P. florida* cultivation on sugarcane bagasse crushed was 66.66 % (the third result from 9 substrates) and BE of *C. indica* cultivation on sugarcane bagasse milled was 71.20 % (the second from 9 substrates) (**Karuppuraj *et al.*, 2014**). Selection of different substrates for the cultivation of *C. indica* shows that the lowest yield was recorded in the treatment of sugarcane baggase (515.7 gm/kg dry substrate) in comparison with wheat straw (1463 gm/kg dry substrate), soybean straw, coconut coir pith and cotton waste (1261 gm, 1087 gm and 920.7 gm/kg dry substrate). The BE was appropriate (**Vijaykumar *et al.*, 2014**). 50 % sugarcane bagasse supplemented with 50 % wheat showed the worst result (yield =760 g, BE =7.6 %) for *V. diplasia* and third result (from seven substrates) for *V. volvacea* (yield =960 g, BE =9.6 %). The best result showed the substrate 50 % rice bran with 50 % wheat for both mushrooms (**Tripathy *et al.*, 2011**). Sugarcane bagasse showed 7th result (yield =641.7, BE =64.1 %) from 13 substrates for *P. sajor-caju* cultivation (**Dehariya and Vyas, 2013**). Thus, despite the promising chemical composition, sugarcane bagasse showed rather mediocre results as substrate and additives thereto.

The sugarcane bagasse became the part of mixted substrate (with seafood processing wastes) in two studies. Seafood processing wastes were mixed with selected agro-industrial wastes (e.g., coir pith, woodchips, sugarcane bagasse) in specific ratio (1:1) (**Lakshmi, 2013**). Not taking into account «control» (sugarcane and coir pith) the highest biological yield (23.15 g/bed) of *G. lucidum* and BE showed mixture coir pith+ fishery waste (1:1). This study was continued by the examination of the utilization of seafood processing wastes for artificial cultivation of edible mushroom *P. flabellatus* in laboratory condition (**Lakshmi and Sornaraj, 2014**). The selected agro-industrial wastes such as coir pith, woodchips and sugarcane bagasse were mixed with cooked fish waste (CFW) in the ratio of 1:1 (500 g : 500 g). The substrates which were not mixed with CFW were treated as control. Not taking into account «control» (sugarcane) the highest biological yield (35.00 g/bed) of *P. flabellatus* and BE showed mixture sugarcane baggase + cooked fish waste (1:1).

Worldwide olive oil production is reported to be about 3,200,000 tons for the years 2013/2014. The liquid effluent of olive oil process, the olive mill wastewater (OMWW), amounts to 0.5–1.5 m^3 per 1000 Kg of olives. **Lechner and Monaldi** (**2011**) examined the use of OMWW at different concentrations for moistening the garlic and maize wastes to produce basidiomes of *P. ostreatus* and to compare with substrate without OMWW. *P. ostreatus* was cultivated in garlic and maize wastes mixed with 15, 30, 45 and 60 % of OMWW. Bags with 0 % OMWW (control) and 100 % OMWW were also inoculated. The BE (129.5 %) and the total yield (388.5 g) obtained permitted to conclude that the best substrate utilized for *P. ostreatus* production was a mixture composed of OMWW (15 %) and maize wastes. The effect in the growth of *P. ostreatus* on garlic wetted with 15 and 30 % of OMWW was the same as for control. OMWW is characterized by high degree of organic pollution chemical oxygen demands. **D'Annibale *et al.*, (2004**) showed that *Panus tigrinus* and *L. edodes* removed toxic phenols from OMWW. **Lakhtar *et al.*, (2010**) investigated sixteen strains of *L. edodes* for their tolerance to OMWW, apical growth rate, and biomass production on agar media. The highest biomass yields were recorded in four strains (Le118, Le119, Le121, Le122) grown in the presence of 20% OMWW. Fifteen fungal strains belonging to five species (Basidiomycota): *Agrocybe cylindracea* (strains IK10 (Greece), IK21 (Greece), and SIEF0834 (China), *P. cystidiosus* (strains LGAM P50 (Greece), LGAM P100 (Greece), and D415 (USA), *P. eryngii* (strains LGAM63 (Greece), LGAM101 (Greece), and UPA10 (Italy), *P. ostreatus* (strains LGAM60 (Greece), LGAM106 (Greece), and LGM850402 (Hungary), and *P. pulmonarius* (strains LGAM10 (Greece), LGAM26 (Greece), and LGM850403 (France), were evaluated for their efficacy to colonize media composed of two-phase olive mill waste (TPOMW), which was used either raw or composted in mixtures with wheat straw in various ratios. Qualified strains exhibited high values of BE (e.g., 120–135 % for *Pleurotus* spp. and 125 % for *A. cylindracea*) and productivity in subsequent cultivation experiments on substrates supplemented with 20–40 % composted TPOMW or 20 % raw TPOMW. The substrates hemicellulose content was negatively correlated with mycelium growth rates and yields and positively with earliness; in addition, cellulose: lignin ratio presented a positive correlation with mycelium growth and mushroom weight for *A. cylindracea* and with earliness for all species examined (**Zervakis *et al.*, 2013**).

The olive oil production is typical for Mediterranean countries, sunflower, rapeseed and other oilseeds (soybean, amaranth, wheat germ) are typical for East Europe countries. The intensity of *P. ostreatus* biomass accumulation (18–24.1

g/l) and high conversion of substrates (33.3–44.6%) have shown prospects for this mushroom cultivation on new substrates such as wheat germ oil meal, CO_2-extraction waste – amaranth flour and rapeseed meal. The optimum concentration of selected substrates were 70 g in 1 liter of distilled water for wheat germ oil meal and amaranth flour, 60 g/l – for rapeseed meal. It was found 17 amino acids, including 9 essential in fungi biomass hydrolyzate. Significant influence of cultivation substrate on quantitative composition of amino acids has been established. To all biomass samples the prevalence of glutamic and aspartic acids, arginine among the nonessential amino-acids, leucine, lysine and cystine among the essential amino-acids were common. Endopolysaccharides content in mushroom biomass and exopolysaccharides in culture liquid were slightly different depending on the selected substrates (**Krupodorova *et al.*, 2014a**). The content of proteins, lipids, amino and fatty acids was investigated in mycelium and culture broth of medicinal mushrooms *Cordyceps sinensis*, *P. ostreatus*, and *Schizophyllum commune* cultivated on amaranth flour (**Krupodorova *et al.*, 2012**). Seven essential amino acids were present in the proteins of all mushroom samples, with aspartic (6.34 %−14.29 %) and glutamic (15.12 %−17.51 %) acids predominating in culture mycelium and glutamic acid (16.3 %−19.1 %) in culture broth. Lipids in the mycelium of species *C. sinensis*, *P. ostreatus*, and *Sch. commune* consisted of 10 fatty acids and 12 fatty acids in culture broth in our experiments. Major acids in culture mycelium and culture broth of fungi were linoleic (42.43 %−67.41 %), oleic (10.47 %−32.54 %), and palmitic (16.43 %−20.33%). The proteins and lipids in culture broth of studied species contained a higher level of total non-essential amino acids and unsaturated fatty acids as compared to those in culture mycelium. **Krupodorova and Barshteyn** (**2012**) studied the ability of medicinal and edible mushroom species from different systematic and ecological groups for biotransformation of CO_2-extraction (*Echinacea purpurea*, *Humulus lupulus*) and food industry (broken vermicelli, flour milling production – grits, confectionery industry – cacao shell) waste. The perspective alternative substrates for 17 mushroom species cultivation have been determined according to biomass accumulation criteria. Sunflower seed hull, an abundant and cheap by-product of the edible oil industry, was used as a substrate for growing *S. commune* (**Figlas *et al.*, 2014**). Mushroom mycelial growth rate on substrates prepared with sunflower seed hull, in absence or presence of supplements (barley, wheat bran, sunflower or olive oil), was evaluated. The growth analysis on sunflower seed hull (37.5 %) substrate showed a mycelial run length of 3.8 cm in seven days. In comparison, supplementation with either wheat bran (3.75 %, 7.5 %), barley (3.75 %, 7.5 %), or 1 % vegetal oils (sunflower or olive oil) improved, but showed no significant differences on mycelial growth. BE and productivity on sunflower seed hull based substrate containing 7.5 % wheat bran (BE = 48.3 %, productivity = 1.6 %/day) were significantly greater than those obtained on sunflower seed hull substrate (BE = 40.7 %, productivity = 1.1 %/day).

Whey (milk and cheese-processing) is one of the main dairy industry waste. Milk whey and starch grits have been studied as substrate (submerged conditions) for the production of several strains of *G. applanatum* and *G. lucidum*. Micro morphological characteristics of vegetative mycelia, biomass yield and exopolysaccharides were investigated. Nutrient medium with milk whey was optimal for biomass growth and synthesis of polysaccharides for investigated cultures. Maximal content of biomass (17.2±0.1 g/l) was produced by *G. applanatum* on the 11th day of cultivation, *G. lucidum* – 29.6 g/l on then 5 day. On the 11th day of growth the highest amounts of exopolysaccharides in *G. lucidum* was 10.0 g/l and in *G. applanatum* – 9.1 g/l (**Krupodorova, 2011**). A medicinal mushroom, *Phellinus linteus*, was successfully cultivated using a cheese-processing waste, whey, and the optimal utilization conditions for the maximum mycelial growth rate was also estimated through solid-state cultivation experiments. The results proved a good potential of whey to serve as an alternative growth medium for cultivating *P. linteus* mycelia. The maximum mycelia growth rate was redacted to be 2.80 mm/day (**Lee *et al.*, 2011**).

The world coffee production increasing rapidly and, consequently, the husk amount as this production waste. Coffee industry wastes: coffee cherry husk, coffee parchment husk, coffee silver skin, coffee spent wastes, coffee dried leaves with and without supplementation of agricultural wastes such as wheat bran were used for cultivation of *P. florida*. When these substrates were used individually, the mushrooms yield was very low. Among individual substrates, highest yield was observed with coffee charry husk. The best yield (220 g) was observed in combination: coffee parchment husk (20 %) + coffee cherry husk (20 %) + coffee silver skin (20 %) + coffee spent wastes (20 %) + coffee dried leaves (10 %) + wheat bran (10 %) (**Murthy and Manonmani, 2008**). It has been studied the suitability of coffee husk for cultivation of *P. ostreatus* after compositing with different main substrate combinations. Composting of coffee waste (husk) was conducted with cow dung, poultry manure and bone meal in the ratio of 3:1. The highest yield (192.3 g) and BE (21.37 %) was obtained from combination of coffee husk (75 %) and cow dung (25 %) on 20 days composting. Therefore, better yield of Oyster mushroom was obtained after utilization of this cost-effective and cheap agro-waste of coffee husk (**Mohammed *et al.*, 2014**).

Tea leaves after hot water extraction (to obtain water-soluble components) are still contains nutrients and are interesting as alternative substrate for mushroom cultivation. Tea waste (TW) was investigated as a new supplement for substrate mixtures in *G. lucidum* cultivation in solid-state fermentation. Sawdust (S) based substrates were supplemented with TW at the various levels (75S:25TW, 80S:20TW, 85S:15TW, and 90S:10TW). The substrate formulations producing highest yield and BE were 80S:20TW (87.98 g/kg substrate and 34.90 %) and 75S:25TW (82.30 g/kg substrate and 31%). Yield and BE of substrates containing TW were generally higher than that of the control (80 sawdust : 18 wheat bran : 1 sucrose : 1 CaCO3). Nitrogen, potassium, iron, and manganese contents and C:N ratios of substrates were strongly correlated with yield. BE showed positive and significant correlations with potassium, iron and manganese. Moisture content, potassium, magnesium, calcium, iron, and zinc contents of the fruiting bodies were affected by both strain and substrate. It was concluded that TW can be used as a supplement for substrate preparation in *G. lucidum* cultivation (**Peksen and Yakupoglu, 2009**). Used tea leaves showed 5th–6th result (yield = 655.0, BE = 65.5 %) from 13 substrates for *P. sajor-caju* cultivation (**Dehariya and Vyas, 2013**). **Yang *et al.*** (**2015**) studied Oyster mushroom cultivation using tea waste as substrate. Substrate containing 40 % – 60 % of tea waste obtained the highest yield.

Several studies devoted to the utilization by mushrooms of waste products of traditional Korean and Mexican beverages. Mycelia of *L. edodes* ASI 3046, which is regarded as the most suitable strain for sawdust cultivation, were cultured on six kinds of previous known media and Sikhae Factory Waste (SFW). As the seven kinds of media were applied, a SFW was most excellent in growth. The dried mycelial weight in SFW was almost four times as much as that in the other media. In the flask culture, optimum culture conditions for the mycelial growth were obtained after 13 days of cultivation. SFW must be a remarkable medium for *L. edodes* because of its simple preparation and low cost (**Jung *et al.*, 2001**). The chemical composition and elemental analysis of *Agave salmiana* and *Agave weberi* bagasse (lignocellulosic residues of mexican Mezcal industry) showed a content of 3.70 % and 3.17 % for protein, 5559 mg/l and 3.23 mg/l for total reducing sugars, 0.73 % and 0.54 % total nitrogen, 3.46 % and 1.95 % calcium respectively. The BE was 70 % in *A. salmiana* bagasse and 40 % in *A. weberi* bagasse, the use of these residues for the cultivation of *P. ostreatus* is feasible (**Heredia-Solis *et al.*, 2014**).

A significant series of investigations (**Petre and Petre, 2011; Petre and Petre, 2012; Petre and Petre, 2013a; Petre and Petre, 2013b; Petre and Teodorescu, 2011; Petre and Teodorescu, 2012; Petre *et al.*, 2014**) devoted to the utilization of fruit, wine making industry and fruit trees wastes. The screening the optimal biotechnology of medicinal mushroom cultivation from the solid-state fermentation and the submerged one by using different kinds of wastes coming from cereal crop processing as well as the agro-food industry is the aim of **Petre and Teodorescu** (**2011**) study. The both fermentation technologies were tested through the controlled cultivation of the medicinal mushrooms *G. lucidum* and *L. edodes* on different growing substrates made of cereal, fruit and vegetable wastes. Among the five nitrogen sources examined, wheat bran was the most efficient upon the mycelia growing and fungal biomass production of *L. edodes* and *P. ostreatus*, at 35–40 g% fresh fungal biomass weight, closely followed by malt extract at 25–30 g%. The best mineral source was $CaCO_3$ that yielded the optimal mycelia growing as well as fungal biomass production at 28–32 g%. The final fruit body production by the two mushroom species was registered between 1.5–2.8 kg per 10 kg of solid composts made from winery wastes. The biotechnological controlled cultivation of edible mushrooms *L. edodes* and *P. ostreatus* was tested (**Petre and Petre, 2013b**) through the submerged fermentation of different fruit wastes from organic horticulture that provided a fast growth as well as high biomass productivity of investigated strains in comparison with the sample. All culture media used in experiments were prepared from different sorts of organic fruit wastes such as juice and pulps, resulted from the industrial processing of apples, pears and plums. The submerged fermentation was carried out inside the culture vessel of an automatic laboratory-scale bioreactor. The microbial strains of *B. subtilis* and *P. ostreatus* were used in pairs as well as separately to compare the efficiency of their biological potential in utilization of fruit wastes into protein biomass (**Petre *et al.*, 2014**). These strains were tested both in monocultures and co-cultures for growing on two variants of culture substrates made of apple and plum wastes mixed with cereal wastes. The optimal temperatures for both bacteria and mycelia cultures to produce microbial biomass through controlled submerged fermentation as mono- and co-cultures, were registered between 23–25°C, corresponding to initial pH levels of 4.5–6.0 and the agitation speed was tested in the range of 30–90 rpm. The registered results revealed an increasing of reducing sugars correlated with the significant level of protein content analysed as total nitrogen for the microbial biomass of co-cultures, in comparison with the control samples represented by the monocultures of the same bacterial and fungal species used in experiments.

A new substrate, breadcrumbs, was investigated for biomass accumulation, the pH of the cultural broth, the formation of primary metabolites such as the proteins and endopolysaccharides of *S. commune* and *T. versicolor*, as well as its utilization efficiency. The results showed that *S. commune* gives more mycelial mass (23.96 g/l) and in a shorter period (4 days) than *T. versicolor* (15.76 g/l) (in 5 days). The pH values changed from the initial 6.1 to 3.6 in *S. commune* cultural broth and to 4.4 in *T. versicolor* cultural broth. Maximal endopolysaccharide content in the mycelia of *S. commune* and *T. versicolor* were 7.13 % and 6.42 %, correspondingly. Crude protein content in *S. commune* mycelium was 18.83 % on the 4th day of cultivation, and 20.03 %, in the mycelium of *T. versicolor*, on the 6th day of cultivation (**Ivanova *et al.*, 2014**).

Three food wastes residues (peas, broad bean, beet pulp) were used in different levels with mung bean straw to prepare mushroom growth media for *A. bisporus*. The total yield was: mung bean straw (2.56 kg/10 kg), mung bean straw + broad bean = 3:1 (2.51 kg/10 kg) (**Al Abttan *et al.*, 2005**).

The aim of the next study (**Yang *et al.*, 2012**) was to evaluate the feasibility of adding citrus peel (pomelo, lemon, orange and grapefruit) extracts to enhance the formation of bioactive metabolites in the submerged culture of *Antrodia cinnamomea*. With the exception of grapefruit, citrus peel extracts tested were proved to be beneficial to mycelial growth and to the production of intracellular polysaccharide. Lemon was the most effective for enhancing bioactive metabolite production. With an addition of 2 % of lemon peel extract, the mycelium biomass concentration and intracellular polysaccharide content rose from 11.96 g/L of the control and 123.6 mg/g to 21.96 g/l and 230.8 mg/g, respectively, on day 8. The production of triterpenoids also increased from 86.7 to 282.9 mg/l.

P. ostreatus hypha has been cultivated on the food wastes (rice, cabbage pickles, egg soup, pumpkin, lettuce, seasoned vegetables, instant noodle, bean sprout, egg) extracts with concentrations 10, 20, 30, 40, and 50 %. The initial pH were set variously with 4, 5, 6, and 7. These were cultured for 9 days at the temperature of 25^{o}C and the rotation rate of 120 rpm. The result is that the mushroom hypha has been grown best at the concentration of fluid – 30 % and the optimal pH was 5 and 6 (**Lim *et al.*, 2009**).

Water from matured coconut was evaluated for schizophyllan production (**Reyes *et al.*, 2009**). *Sch. commune* ATCC 38548 was used as the test strain. Results of the investigation showed that coconut water could stimulate the growth of *Sch. commune* with subsequent production of schizophyllan at 7.71g/1000 ml 4 days after incubation which is a day earlier than in the two semi-synthetic media. The basal semi-synthetic and the triple sugar- enriched media yielded 6.69g and 3.99g of schizophyllan per 1000 ml of the medium, 5 days after incubation, respectively.

The contents of Ca, Mg, Na, and K in fruiting bodies (FB) of *G. lucidum*, *L. edodes*, and *Pholiota adipose* have been determine in **Jo *et al.***, (**2013**) study. The objectives of this study were to evaluate applicability of food waste compost (FWC) as a substrate for cultivation of *G. lucidum*, *L. edodes*, and *P. adipose*. FB yield per substrate in FWC-free controls was 53 g/Kg for *G. lucidum*, 270 g/kg for *L. edodes*, and 1,430 g/Kg for *P. adipose*. Substrates supplemented with FWC showed the highest FB production at FWC content of 10 % for *G. lucidum* (64 g/Kg), 13 % for *L. edodes* (665 g/Kg) and *P. adipose* (2,345 g/Kg), which were 1.2~2.5 times higher than the values for the controls. *P. adipose* contained higher amounts of mineral elements than the other species. Ca, Mg, Na, and K content in FB did not show a significant relation to FWC content.

Large amounts of food waste attached to actuality of the search for possible utilization, in this case – by higher fungi. New components of substrates: milk whey, fishery waste, fruit waste, winery wastes, oil industry wastes, and food waste compost are characteristic for the majority of the countries of the word and therefore are promising for their utilization by higher fungi. Utilisation of food wastes using Macromycetes is a perspective direction, oriented to satisfaction of the global demand for food protein, nutritional supplements and natural drugs.

CONCLUSIONS

The dynamic increase of agricultural production can not keep up even more rapid growth of the world population, but leads to the accumulation of large amounts of waste. Waste management and providing a world population with rich in protein food is two important problems of which the utilization of agro-industrial (agriculture and food industry) waste by higher mushrooms causes the growing interest of researchers around the world. Not all mushrooms are edible, but many of not edible mushrooms exhibit various types of therapeutic activity, and at the same time are capable for wastes biodegradation. More than 150 individual types of wastes have been investigated as alternative substrates alone or in various compositions (more than 450 substrates) for cultivation of 52 higher mushroom species (about 100 strains) as evidenced by the results of more than 130 considered in the review scientific publications. All waste is used as a basis for substrates and supplements thereto, are characteristic of the respective continent and region of the world. Alternative substrates will be an integral part for the waste management technology.

Majority of mushrooms listed in the review are wood-decay one's, so the basis of most substrates is lignocellulosic feed stocks (different kinds of sawdust, woodchips, straw, grasses, hulls, etc.). Extremely difficult to determine the regularities that affect the morphological parameters, yield and biochemical composition of different mushrooms, depending on the qualitative and chemical composition of the substrate. Good results are obtained with the combined substrates. Publications containing biochemical studies of substrates and fungi confirm that fungi are grown on unconventional substrates rich in biologically active substances, provide a rich biochemical composition of fungi compared with conventional substrates (sawdust, straw, etc.).

The disadvantage of many publications is the lack of mention of examined fungi strains, whereas studies of various strains of the same fungus on the same substrate show different results.

A very important problem escapes the attention of researchers. Most agricultural wastes (various kinds of sawdust, straw, leaves, grasses, etc.) contain toxic substances which can be accumulated by mushrooms, primarily – heavy metals, herbicides, pesticides, the amount of which in grown mushrooms is not determines. Food waste is most often free from this drawback, as the food raw material supplied according to regulatory documents, including the safety performance.

The prospect of the study of agricultural residues utilization by higher mushrooms consists in the investigations of: productivity, biological efficiency of the process, morphological and biochemical indices of cultivated mushrooms, depending on the biochemical parameters of substrates and the process conditions; safety of cultivated mushrooms.

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