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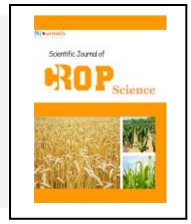

Review article

The influence of substrate on mushroom productivity

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Utilization of different agricultural waste for production of different species of mushroom could be more economically and ecologically practical to meet the nutritional and health needs of ever increasing world population. Mushrooms are grown on a great variety of substrates and the choice of substrate depends on availability and cost. This is on the background that momentous variation on biological efficiency, mushroom nutritive content and yield on different substrate weight have been reported worldwide. This discussion attempt to explore the influence of substrate on mushroom productivity parameters. The use of additives to imrove biological efficiency is highlighted as means of increasing mushroom production. The influence of substrate type and weight have been assessed on mushroom yield to ascertain the exact weight for optimal weight of production. In certain cases mushroom yield have increased with increased in substrate type and weight. Different biological efficiency have been associated with different substrates supplemented with different additives resulting into specific nutritional composition of the product. It is reasonably to suggest that in order to be able to adequately address issues related to mushroom productivity, there is need for thorough assessment of the effects of different substrates on mushroom yields. Thus, interventions that seek to improve mushroom production need to consider the trade-offs inherent in availability and suitability of substrates in mushroom cultivation.

1. Introduction

Mushroom are increasingly becoming an important component of diets worldwide (Ajonina and Tatah, 2012), because of their high nutritional value and medicinal properties (Chang and Buswell, 1996; Miles and Chang, 1997; Chang and Miles, 2004). They are a good source of protein, vitamins and minerals (Kimenju et al., 2009.). Also, are important nutritionally because of their higher protein, dietary fibers and important mineral contents (Khan et al., 2009). Mushroom have anticancerous, anticholesterol and antitumorous properties and are useful against diabetes, ulcer and lung diseases (Quimio, 1980; Wasser, 2005). This is on the background that mushrooms have been recognized as a high potential converter of cheap celluloses into valuable protein (Poppe, 2000). The rapid growth and the ability to utilize various lignocellulosic substrates, make different mushroom species cultivation possible in different parts of the world. Substrate type is one of the major factors affecting the yield and quality of oyster mushroom (Chitamba et al., 2012). A substrate in mushroom cultivation may be defined as a kind of lingo cellulose material which supports the growth, development and fruiting of mushroom (Chang and Miles, 1988). Most of all edible mushroom species can utilize various kinds of substrate materials depending on availability in different places. The nutrient composition of substrate is one of the factors limiting the saprobiotic colonization of cultivated mushrooms (Tshinyangu and Hennebert, 1995). The growth of microorganisms as well as quantitative and qualitative yield of the desired product depends on the utilization of nutrients and physiochemical environment in the medium or substarte (Mukhopadhyay et al., 2002). Obodai et al. (2003) found eight lignocellulosic by-products as substrates for cultivation of the Oyster mushroom, Pleurotus ostreatus. The yields of mushroom on different substrates were 183.1 g, 151.8 g, 111.5 g, 87.8 g, 49.5 g, 23.5 g, 13.0 g and 0.0 g for composted sawdust of Triplochiton scleroxylon, rice straw, banana leaves, maize stalk, corn husk, rice husk, fresh sawdust and elephant grass respectively and rice straw give the best yield. Elsewhere, in a descending order of suitability of substrates bean, rice, finger millet and wheat straw were recommended for smallholder mushroom production (Kimenju et al., 2009). Therefore, the growth of diverse type of mushrooms require different type of substrates and availability of varied type of materials may dictate which type is used (Shah et al., 2004). Substrates enriched by plant origin complements lead to a slow release of organic materials which could be taken up by the mycelium structures (Royse et al., 1991). Kumar et al., (2004) reported the successful cultivation of oyster mushroom on conventional substrates sufficiently available which are not utilized properly and productively. This discussion attempt to explore the influence of different substrate on mushroom productivity.

2. Substrate and mushroom yield

The presence of right proportion of alphacellulose, hemicellulose and lignin was the probable cause of higher rate of mycelium running in corn cobs and palm cones. Buswell et al., (1993) suggested that the utilization of insoluble ligno-cellulosic substrates by edible mushrooms depends on the production of the enzymes such as cellulases, hemicellulases, ligninases which bring about hydrolysis of the macro molecules of cellulose, hemicellulose and lignin components of the substrate, thereby liberating the low molecular weight nutrients essential for mushroom growth. In another study, saw dust acting as a substrate gave the lowest mycelium running rate, which might be due to presence of different kinds of polyphenolic substances in them as suggested by Wang (1982) and low content of cellulose (Gohl, 1993). Suitable C: N ratio might be responsible for the higher mycelial growth in corn cobs and palm cones. Quimio and Sardsud (1981) reported similar results, whereby the optimum days to complete mycelium running in spawn bags ranged 21.00 days to 24.06 days on different substrates. Groundnut hull had the least oyster mushroom yields which is contrary to observation by Poppe (1995) who reported that legume straws, mostly rich in N, was suitable as Pleurotus substrates. Maize stalk had the least biological efficiency of 39.88± 4.59, which was lower than maize straw biological efficiency of 52% for Pleurotus sajor- caju (Pani et al., 1997). Cereal straw has 0.5% total N, 38% cellulose, 15% lignin, C/N = 90 (Kaul et al., 1981), which suggest that basic substrate for oyster mushroom may need to be enriched with different additive to maximize production. Royse et al., (2004) suggested that physical processing of substrates material such as maize stalk through milling, may improve yield potential. The appreciable days to complete mycelium running of oyster mushroom on different substrates might be due to variation in their chemical composition and C: N ratio as reported by Bhatti et al. (1987) and Mondal et al (2010). The same author suggested the mixing of wheat straw with other organic material to improve mushroom production. Maximum yield (weight of fresh mushrooms harvested at maturity) was obtained on cottonseed hull/wheat straw substrate at a 3.75-5% spawn level and 6% S-41 supplement however, on switch grass substrate, increasing spawn levels and supplement levels stimulated yields in a linear fashion. Comparing rice straw with wheat straw, rice straw yielded about 10% more mushrooms than wheat straw under the same cultivation conditions (Zhang et al., 2002). However, this was depended on ground straw yielding higher mushroom growth rate and yield than the chopped straw. This means apart from the substrate type particle size had an effect on mushroom yield. Sainos et al., (2006) observed high activity of proteases and high content of intracellular protein in cultures grown on wheat straw, as a result the proteases were not secreted into the medium where protein is an important cellular reserve. On the contrary, cultures grown on wheat straw secreted laccases into the medium, which could be induced by this substrate. P. ostreatus grown on media prepared with a combination of wheat straw and wheat grain showed a high radial growth rate. This result showed that cheaper and more productive mushroom spawn can be prepared by developing the mycelium on wheat straw and wheat-grain-based substrates. Using off-line thermochemolysis with tetramethylammonium hydroxide and solid-state (13)C NMR in the molecular characterization of the undegraded wheat straw and the degraded samples Vane et al., (2001) observed that the degraded wheat straw samples had a lower proportion of syringyl- to guaiacyl-derived moieties and cinnamyl- to guaiacyl-derived moieties than the undegraded control. There were increases in both guaiacyl and syringyl acid to aldehyde ratios with composting time, which showed that side-chain oxidation has been mediated by P. ostreatus as a result there was a decrease in amorphous noncellulosic polysaccharides in relation to the crystalline cellulose upon degradation. This whole process influence the growth of mushroom on the wheat straw.

3. Substrate and biological efficiency

The biological efficiency varied significantly due to the effect of different substrate composition on the different flushes. The highest biological yield (146.1g) was obtained from corn cobs and the lowest biological yield (27.38g) was obtained from corn cobs and palm cones (1:3) in the first flush (Ajonina and Tatah, 2012). Wheat straw was found to have the highest biological efficiency (66.88±4.59) followed by hay (41.88±4.59), groundnut hull (40.00±4.59) and maize stalk (39.88±4.59) (Assan and Mpofu, 2014). However, the biological efficiency decreased with increase in substrate weight per bag and substrate weight did not influence the days to fruiting. Gitte et al., (2014) observed the biological efficiency of different substrate which ranged from 51.57 - 146.3 %. the highest biological efficiency 146.3% was observed in wheat straw. The next best in order was paddy straw- 132.4%. Whereas, soybean straw coconut coir pith and cotton waste performed 126.1%, 108.7 % and 92.07% biological efficiency, respectively. Wheat basal substrate had a faster mycelial growth rate, comparatively poor surface mycelial density, shorter total colonization period and days from bag opening to primordia formation, lower yield and biological efficiency than that on cotton seed hull basal substrate (Yang et al., 2013). Increasing the weight of different substrates can increase the total yield per season but reducing the biological efficiency. However, the time of cultivation may significantly influence mushroom yield and biological efficiency, but some undesirable characteristics, i.e. more spoiled mushroom in January to March(Assan and Mpofu, 2014). Obodai et al. (2003) reported a biological efficiency ranging from 61 to 0% for P. ostreatus. This could be due to the different substrate formulations and strain variations. However, the highest fruiting body number (36.33), fruiting body weight (31.17 g), yield (1039 g), and biological efficiency (207.8 %) belonged to wheat straw complemented by either wheat or rice bran (Mehrdad et al., 2011). Nunez and Mendoza (2002) reported biological efficiency values varying from 50.8 to 106.2 % in Pleurotus ostreatus on different substrates. This decrease in yield and biological efficiency could probably be explained by the fact the increase in some supplements might influence generation of heat resulting in the overheating of the substrate which subsequently affected the mushroom growth negatively thereby leading to poor yield. Therefore the time and environment of cultivation possibly room temperature with adequate cooling facility in mushroom growing house may improve production in certain cases. The physiochemical properties of substrates might differ in favour of the spread of mycelia from the applied spawn bits increasing the net inoculums in the cultivation substrate.

4. Influence of additives on mushroom yield contributing parameters

Nutritional supplementation of cultivation substrate is an important cultural practice of mushroom cultivation (Ayodele and Okhuoya, 2007). Most of the growth, yield and quality parameters varied significantly when mushrooms were cultivated with different levels of supplementation (Mahbuba et al., 2010). Substrate supplementation with various additives including nitrogen sources has been reported to improve growth, yield and quality of mushrooms (Khare et al., 2010; Onyango et al., 2011). They usually change the decomposition rate and the sequence of decomposition of substrate components (Zadrazil, 1993). In most cases the efficiency of agricultural waste acting as substrates is considerably enhanced when supplemented with protein-rich materials (Frimpong–Manso et al., 2011). Jadhav et al., (1998) concluded that supplementing substrates with nutrients increases yields of *Pleurotus sajorcaju mushroom*. Various supplements (urea, ammonium sulphate, gram flour, soybean meal, mustard cake, cotton seed cake, and molasses) are recommended as substrate supplements prior to spawning to enhance oyster mushrooms (Naraian et al., 2009). Dhanda et al. (1996) reported that substrate supplementation is a practice used in producing Pleurotus sp. in order to increase its productivity. Inclusion of additives to mushroom substrate is very important especially for substrates having low protein content to enhance the growth and yield of mushrooms. Most agricultural waste used as substrates are lignocellulosic materials which are generally low in protein, which is insufficient for commercially cultivating mushrooms. These agricultural wastes require different supplements or additives with sufficient amounts of nitrogen, phosphate, potassium, and vitamins for better growth and yield of mushrooms (Mangat et al., 2008). According to Moda et al. (2005) supplementing the substrate is a common method to increase productivity, which is evaluated by biological efficiency. The most common supplements are sources of organic nitrogen such as cereal bran, which are necessary for growth of the mycelial mass but may interfere with the productivity and biological efficiency of the mushrooms. Zadrazil and Brunnert, (1980) suggested that in general, the number of fruit bodies per flush recorded decreased from flush to flush indicating that the nature and amount of nitrogen available in a substrate after each flush influence the degree of cellulose degradation which in turn affects the yield Thus, the high C/N ratio of 100% rice husk determined as 204.3 by Youri (2004) greatly affected the yield of the mushrooms. The ratio of carbon to nitrogen (C:N) is critical and plays an important role in mushroom growth. The low amount of available nitrogen (N) in the ligno-cellulosic substrate of wood components is often considered as a limitation to its use as mushroom substrate(Tajudeen et al., 2012). Nitrogen supplementation is also an important factor for developing fruiting bodies and spawn running on mushrooms (Naraian et al., 2009). Royse et al., (2004) assessing the yield, mushroom size and time to production of *Pleurotus cornucopiae* (oyster mushroom) grown on switch grass substrate spawned and supplemented at various rates, observed that increasing the amount of supplement resulted in an increase in biological efficiency up to 30% and then the efficiency decreased again. They concluded that such a reduction in biological efficiency may be due to the compactness or poor aeration of the substrates, which results from insufficient utilization of nutrients. However, this could be also related to the limitation of spaces or surfaces for developing fruiting bodies. In a different study by Frimpong–Manso et al., (2011) evaluating rice husk as a possible additive to composted sawdust of Triplochiton scleroxylon to ascertain its contribution to the biological efficiency and nutrient content of Pleurotus ostreatus (Jacq. ex. Fr.), based on increases in both the biological efficiency and proximate composition of Pleurotus ostreatus strain EM-1, the author recommended that rice husk at 2% concentration can be used as an alternate additive for producing more nutritious mushrooms. The yield of mushroom was increased with the level of each supplementation upto a certain level, and then decreased (Mahbuba et al., 2010). Nuhu et al., (2010) observed the highest biological and economic yield and biological efficiency with 30% maize powder as a supplement. They concluded that increasing the supplement level resulted in less biological efficiency, and that 30% maize powder was the best supplement level for rice straw substrate to cultivate milky white mushrooms. Using wheat bran at 15% supplementation of fermented pine sawdust Tajudeen et al., (2012) proved it to be a viable option for oyster mushroom and recommended for commercial use while any supplementation above this level would reduce the yield of oyster mushroom significantly. However, Royse et al. (1990)] and Oei (2003) suggested the inclusion of wheat bran supplement at the rate of 10-40 % and 5-10 %, respectively would serve as nutrients that will provide optimum growing medium in the substrate ingredients used for mushroom production. Supplementation at 2% gave the best biological efficiency of 75.3%., followed by the control (no rice husk) with a biological efficiency of 68.2% showing a significant difference (P≤0.05) of 11% increase (Frimpong–Manso et al., 2011). From this scenarios, can conclude that the composition of the substrate used greatly influences the biological efficiency values obtained in mushroom production(Chang Ho and Yee, 1977;

Chang and Miles, 1982). Addition of supplements to the cultivation substrate showed varied effects on the sporophore production (Pani, 2011). The biological efficiency of the fungus was reduced by the addition of saw dust and coir pith to the cultivation substrate. This might have been due to the carbon to nitrogen imbalance in saw dust due to the higher lignin content and poor physical make up which might have retarded the performance of supplements (Raja and Ganesh, 2013).

5. Implications

The use of agricultural by-products and additives to improve the total yield, biological efficiency and nutritive value of different edible mushroom species should be an area which needs continuous research. It seems there is a significant interaction between substrate and additive levels of supplementation. Optimal levels of supplementation by different additives for different substrates should be ascertained to maximize mushroom production and improve the nutrive values of different mushroom species. Therefore, it is recommended that farmers should use local available substrates with appropriate levels of supplementation suitable for that particular substrate. It should be acknowledged that the composition of the substrate used greatly influences the biological efficiency values obtained in mushroom production. Substrate for mushroom cultivation should depend on economic feasiblity due to its abundant availability, and possibly throughout the year. Therefore, it is of paramount importance to choose appropriate substrates in a given place to grow mushroom. The disposable of agricultural waste sometimes causes significant problems in terms of environmental pollution. Hence, the ability of mushroom as high potential converter of cheap celluloses into valuable protein should be taken advantage of in the quest of minimizing environmental pollution. This is in addition to the improvement of nutritional and health benefits accrued from consumption of mushroom by the genarl populace.

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