Evaluating the effect of gamma radiation on eight different agro-lignocellulose waste materials for the production of oyster mushrooms (*Pleurotus eous* (Berk.) Sacc. strain P-31)

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Summary

The influence of 15 kGy dose of gamma radiation on the performance of eight lignocellulose agro-wastes for mushroom (*Pleurotus eous, P-31*) cultivation was evaluated. The agro-wastes investigated included coconut coir, rice husk, rice straw, banana leaves, cassava peels, corn cobs, elephant grass and sawdust (control). Corn cobs performed overall best with 23.2 mm/day, 13 days, 9 days, 0% and very dense for spawn running parameters studied which were the rate of mycelia colonization, time taken to complete colonization, percentage contamination and mycelia density respectively. Also recorded for growth parameters were 95 mm for cap diameter, 80 mm for stipe length, 52 for number of primordia, 51 for number of fruit bodies, 6.5 for mushroom size and 9 days for time between flushes. The biological efficiency (B.E %) was 63%, mushroom yield was 377 g and biological yield recorded was 0.63 g/g substrate. The gamma irradiated substrates significantly (p<0.05) influenced both growth and yield of mushroom differently. The results of this study revealed that gamma irradiation could be used as an alternative method for the pretreatment of lignocellulose agro-wastes substrates for mushroom cultivation.

Keywords: Gamma radiation, lignocelluloses, oyster mushroom, *Pleurotus eous*, agro-wastes

1. INTRODUCTION

Oyster mushrooms (*Pleurotus spp.*) are gaining so much popularity in Ghana (Obodai et al., 2002; Apetorgbor, 2005) owing to their exceptional culinary (Kalac, 2009; Zhang et al., 2011), nutritional (Ferreira et al., 2009; Ferreira et al., 2010), medicinal (Singh et al., 2012; Oyetayo and Ariyo, 2013) nutraceutical (Ferreira et al., 2010; Cohen et al., 2002), bioremediation (Hirano et al., 2000; Kubatova et al., 2001) attributes. As primary decomposers, their mycelia grow rapidly and also have the powerful ability to degrade lignocellulose biomass (Baysal et al., 2003). Oyster mushrooms (*Pleurotus spp.*) are found naturally growing in the wild on dead organic matter from tropical and temperate regions (Thakur et al., 2001; O.E.C.D., 2005; Ayodele and Akpaja, 2007). In Ghana, *Pleurotus* species are cultivated on composted sawdust of *Triplochiton scleroxylon* (Obodai et al., 2002). The unavailability of sawdust in some regions of Ghana and the increase in demand for wood shavings by poultry farmers makes it competitive for mushroom cultivation so it’s imperative that other sources of substrates and additives be utilized for *Pleurotus* species cultivation (Owusu-Boateng, 2001; Ajonina and Tatah, 2012). Research in artificial cultivation has made it possible to add novel substrates to the existing wide range of agricultural and industrial waste materials such as: wastes from cereal straw, maize cob, cotton crop residues, forest sawdust, coffee bean residues, cashew-nut residues, sugar cane bagasse, cassava peels, banana leaves, brewery wastes, water hyacinth biomass, waste paper, etc. (Phillipoussis et al., 2001; Obodai et al., 2003; Orts et al., 2008; Kirbag and Akvuz, 2008, Saber et al., 2010; Kortei, 2011).

Prior to cultivation of mushrooms, the substrates are sterilized to achieve a medium which is exclusive to the mushroom spp. thus reducing competition (Gbogalade, 2006). According to Kortei et al., (2014 unpublished), the existing sterilizing technology available in Ghana is drum pasteurization which has some precints such as its incapability to effectively reduce competitive microorganisms, limited pasteurizing capacity, slow rate of pasteurization, laborious etc. Alternative methods of substrate sterilization for mushroom cultivation have not been fully exploited in Ghana hence the need to employ versatile technologies available like gamma irradiation. Although various methods of pretreatment have been reported (Jeoh and Agblevor, 2001; Bigelow and Wyman, 2002; Martin and Thomsen, 2007), few reports exist on the use of gamma irradiation (Martínez et al., 1995; Lam et al., 2000) to achieve such desired results.

Gamma rays come from spontaneous disintegration of radioactive nuclides (Cobalt 60 or Cesium 137) as their energy source (Mami et al., 2013). They have short wave length, high energy photons, and have deep penetrating power. During irradiation, the radioactive nuclides are pulled out of storage (water pool) into a chamber with concrete walls that keep any gamma rays from escaping (Park and Vestal, 2002). Gamma irradiation technology promises to be a potential in this field in view of the fact that it has the ability to sterilize more compost bags per unit time, less laborious, more effective microbial reduction and hydrolytic agent (Gbedemah et al., 1998).
Due to the easy access to gamma irradiation facility and the fact that mushroom production has evolved from an art into a huge agri-business in Ghana, this work was carried out to assess the performance of oyster mushrooms (*Pleurotus eous*) on different gamma irradiated lignocellulose materials.

2. MATERIALS AND METHODS

The research was conducted at Mycology Unit of the Food Research Institute of the Council for Scientific and Industrial Research, Accra, Ghana from November 2013 to February 2014.

2.1 Pure culture

One-week-old pure tissue cultures of *Pleurotus eous* (Berk.) Sacc. strain P-31, were obtained from the National Mycelium Bank at the CSIR- Food Research Institute, Ghana. Each of the bottled sterilized grains was aseptically inoculated with one 1cm² of the one-week-old tissue culture of the experimental strain grown on Malt Extract Agar (OXOID™ Ltd., Basingstoke Hampshire, England) using a flamed and cooled scalpel in a laminar flow hood. Thereafter, the spawns were incubated for 16-21 days without illumination in an incubator. Thereafter, the spawns were harvested after 16-21 days of incubation in an incubator (Tuttlingen™WTC Binder, Germany) set at 28°C.

2.2 Spawn preparation

Moist heat sterilization

The spawns were prepared using a modified form of the method of spawn preparation outlined by Narh et al., (2011). The cereal grains used was sorghum obtained from the Madina Market in Accra, Ghana. The grains were separately washed and steeped overnight in water. They were then thoroughly washed separately with tap water to ensure that dust and other particles had been removed, drained, tied in a wire mesh and steamed for 45 mins in an autoclave (Priorclave, Model PS/LAC/EH150, England) at 121°C to 1hr. mycelium) were recorded by using a string and a centimeter scale. Broken grains are more prone to contamination. Thereafter, they were air-dried to cool on a wooden frame with a wire mesh. To each grain, 3 percent (w/w) of calcium carbonate (CaCO₃) was added and thoroughly mixed manually. The grains were sterilized in an autoclave (Priorclave, Model PS/LAC/EH150, England) at 121°C for 1hr.

2.3 Substrate preparation and spawning

All substrates were prepared as described by Obodai et al., (2002) with modifications. Corn cobs, banana leaves, elephant grass, rice straw, rice husks, cassava peels and coconut coir were chopped into about 3 cm lengths and soaked in water overnight in basins. Excess water was drained and the substrates were subjected to these different treatments to ensure maximum yields). The bags were then incubated at 26-28°C and 60-65% RH for 20-34 days in a well-ventilated, semi-dark room. The mean radial growth per week and the spawn run period to total colonization (i.e. the number of days from inoculation to complete colonization of the compost bag by the mycelium) were recorded by using a string and a centimeter rule (Nge’tich et al., 2013).

2.4 Determination of moisture

This was done according to AOAC (1995).

2.5 Determination of pH

This was done according to (AOAC, 1995) with modifications. Two (2) grams of composted substrate was weighed into a conical flask containing 10 ml distilled water and allowed to stand for 2 hours. A standard pH meter (3510 Jenway, U.K) was used to measure the Hydrogen ion concentration.

2.6 Irradiation of compost bags

One kilogram (1kg) of each substrate type were packed into 33 x 18 cm² heat resistant polypropylene bags and irradiated at a dose of 15 kGy at a dose rate of 1.7 kGy per hour in air from a Cobalt-60 source (SLL 515, Hungary). Absorbed doses were confirmed using the ethanol-chlorobenzene (ECB) dosimetry system at the Radiation Technology Centre of the Ghana Atomic Energy Commission, Accra, Ghana. Each treatment was replicated four (4) times.

2.7 Inoculation and Incubation

Each bag was closed with a plastic neck and plugged in with cotton and inoculated with 5 g sorghum spawn (the substrates were subjected to these different treatments to ensure maximum yields). The bags were then incubated at 26-28°C and 60-65% RH for 20-34 days in a well-ventilated, semi-dark room. The mean radial growth per week and the spawn run period to total colonization (i.e. the number of days from inoculation to complete colonization of the compost bag by the mycelium) were recorded by using a string and a centimeter rule (Nge’tich et al., 2013).

2.8 Fructification and Harvesting

Yield per flush was tabulated to observe changes in yield over the course of multiple flushes. Seven aspects of crop yield were evaluated according to some authors (Amin et al., 2008; Tisdale et al., 2001). Humidity was kept as high as possible 80-85% by watering the cropping floor twice a day. Stipe length (length of cap base to end of stalk) and Average cap diameter = longest + shortest cap diameters/2. Dates of each harvest were also recorded. Total number of flushes (flush number) produced per each bag was noted at the end of four weeks period. The distribution of the yield per flush was tabulated to observe changes in yield over the course of multiple flushes. Seven aspects of crop yield were evaluated according to some authors (Amin et al., 2008; Tisdale et al., 2001; Morais et al., 2000) as follows: (i) Mushroom size (MS). (ii) Biological efficiency (BE) = Weight of fresh mushrooms harvested (g) /dry substrate weight (g) x100 (iii) flush number (iv) crop period (sum of incubation and fruiting periods) (v) Fresh weight. (vi) BY= [Weight of fresh mushrooms
Table 1. Influence of gamma radiation on the physical properties before irradiation of eight lignocellulose agro wastes

<table>
<thead>
<tr>
<th>Substrate</th>
<th>pH</th>
<th>Temperature (°C)</th>
<th>Moisture content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconut coir</td>
<td>6.11 ± 0.08</td>
<td>24.40 ± 1.50</td>
<td>61.20 ± 1.0</td>
</tr>
<tr>
<td>Banana leaves</td>
<td>5.95 ± 0.08</td>
<td>24.40 ± 1.50</td>
<td>60.30 ± 1.0</td>
</tr>
<tr>
<td>Elephant grass</td>
<td>5.79 ± 0.11</td>
<td>24.10 ± 1.50</td>
<td>63.14 ± 1.2</td>
</tr>
<tr>
<td>Rice husk</td>
<td>5.40 ± 0.08</td>
<td>23.93 ± 1.50</td>
<td>61.70 ± 1.0</td>
</tr>
<tr>
<td>Corn cobs</td>
<td>6.07 ± 0.09</td>
<td>24.27 ± 1.50</td>
<td>62.10 ± 1.0</td>
</tr>
<tr>
<td>Rice straw</td>
<td>5.34 ± 0.08</td>
<td>24.02 ± 1.50</td>
<td>60.82 ± 1.0</td>
</tr>
<tr>
<td>Cassava peels</td>
<td>6.13 ± 0.08</td>
<td>23.55 ± 1.50</td>
<td>62.56 ± 1.2</td>
</tr>
<tr>
<td>Sawdust</td>
<td>5.42 ± 0.08</td>
<td>24.50 ± 1.50</td>
<td>62.81 ± 1.2</td>
</tr>
</tbody>
</table>

harvested (g) per dry substrate weight] and was expressed as kg fresh mushrooms/kg dry substrate weight. Also, economical or mushroom yield values were calculated as previously reported by Morais et al. (2000) as weight of fresh mushrooms harvested (g)/ fresh substrate weight. The average MS was calculated as total fresh weight of mushrooms harvested divided by their total number of mushrooms. BY = [Weight of fresh mushrooms harvested (g) per dry substrate weight] and was expressed as g fresh mushrooms/kg dry substrate weight according to Amin et al. (2008). Average weight of individual mushrooms was determined as quotient of the total fresh weight mushrooms harvested by their total numbers according to Phillipoussis et al (2001). Economical Yield (g/kg wet sawdust) = Total fresh weight of mushrooms. N.b- Dry weight of substrates - 600 g

Moisture content of the substrates ranged between 60.30±1.0 - 63.14±1.2% for banana leaves and elephant grass respectively. Low moisture content below a critical level (<30%), would decrease activities of microorganisms by restricting the motility and make them dormant (Hubbe et al, 2010). Under drier conditions, the ammonium and ammonia present generate a higher vapor pressure; thus conditions are more favorable for nitrogen loss. On the other hand, a moisture content which is too high (>65%) could cause oxygen depletion and losses of nutrients through leaching (Tiquia et al, 1996). It has been observed that where the excess water sets at the bottom of the substrate, the mycelia colonizes the substrate just to the level of the water. A higher contamination rate by bacteria has also been observed where there is excess moisture.

3.1 Average Mycelia Growth Rate

The influence of gamma radiation on the different agro-lignocellulose wastes resulted in significantly (P<0.05) different growth rates of *Pleurotus ostreatus*. Nutritional composition of substrates has been reported to be crucial in determining how mycelia growth initiation occurs (Stanets, 2005) and also due to the available proportions of carbon and nitrogen. The fastest mycelia growth rate recorded was 23.2±0.4 mm/day for corn cobs (Table 2). High dosage gamma radiation used on lignocelluloses, might have caused a decrease in cell wall constituents or depolymerized and delignified the corncob fiber (Al-Masri and Zarkawi, 1994) and grew amidst favorable environmental conditions. The results obtained agreed with results of some researchers (Kortei, 2011; Stanley and Odu, 2012; Nge’itch et al, 2013) as they observed very abundant mycelia growth on corncobs.

While the slowest rate of growth was 0 mm/day for elephant grass (Table 2). The abysmal performance of elephant grass could be attributed to its unfavorable environmental conditions created by the relatively high moisture content which might have caused anaerobic conditions to accumulate substances toxic to *Pleurotus* mycelia (Kortei, 2008). Obodai et al, (2003) observed no mycelia growth on elephant grass as they studied the growth and yield of *Postreatus* on different lignocellulose by-products.

3.2 Time of Colonization

The duration of mycelia invasion differs depending on the type of substrate used (Stanley, 2010). The shortest time of 13 ± 0.3 days (Table 2) was observed for mycelia growth on corn cobs. The time of colonizing and rate of growth of
mycelia is directly related to nutrient availability in the substrate or inability to effectively utilize lignocellulose materials available as well as C: N ratio is suspected to have affected the growth and development of *P. ostreatus* mycelia (Thomas et al., 1998; Wong et al., 2006; Kortei, 2011). The longest time of 31±0.9 days (Table 2) for complete mycelia colonization was observed for cassava peel substrate suggesting a poorly aerated environment conditions to stimulate primordial formation. The rest of the substrates exhibited no contaminations and supported mycelia growth. Comparison of data with results from work of (Oseni et al, 2012), indicate that contamination was minimal.

Influence of ionizing radiations on microorganisms according to Lele et al, (2011) could be either direct or indirect interactions (electrons or photon association with atoms). The DNA molecules of microorganisms are often the main target of destruction by ionizing radiations causing a change (permanent or temporal) to affect its reproduction, survival or ultimate death (Moreira et al, 2010). Kurtzman (2010) reported several causes of contamination of mushroom substrate and ways of avoiding potential contamination. Some researchers have implicated *Penicillium* and *Trichoderma* spp. as abundant contaminants (Oseni et al, 2012). Obodai et al (2010), reported *Aspergillus* spp. and *Rhizopus* spp. as responsible for contaminations 33.3% was recorded by rice husk followed by 16.6% by both coconut coir and rice straw substrates. The rest of the substrates exhibited no contaminations and supported mycelia growth.

### 3.3 Time taken till appearance of primordia

Primordia emergence according to Narain et al, (2008) is directly related to the availability of carbon and nitrogen (C: N) from lignocellulose materials and ultimately to mycelia density. Gamma radiations aid to depolymerize the complex lignocellulose structure and make it easy for assimilation and utilization of metabolites from the other microorganisms which inhibited mycelia growth. Mycelia vigor is directly linked to optimal nutrients, pH, temperature and other physico-chemical properties of the substrate (Nwanze et al, 2005). They were in the range of very dense mycelia to no mycelia growth. These values were consistent with the percentage (%) contamination. Generally, all the substrates resulted in visually good mycelia. Conversely, elephant grass substrate resulted in the poorest mycelia growth. Comparison of data with results from work of (Oseni et al, 2012), indicate that contamination was minimal.

Means with same letters in a column are not significantly different (P>0.05)

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Av. rate of colonization (mm/day)</th>
<th>Time of colonization (days)</th>
<th>Time taken till appearance of primordia (days)</th>
<th>% Contamination</th>
<th>Mycelia surface density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconut coir</td>
<td>13.5 ± 0.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>30.0 ± 0.5&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>4.0 ± 1.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>16.7 ± 1.2</td>
<td>++</td>
</tr>
<tr>
<td>Banana leaves</td>
<td>20.4 ± 0.4&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>26.0 ± 0.4&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.0 ± 1.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.0 ± 0.0</td>
<td>+++</td>
</tr>
<tr>
<td>Elephant grass</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td>Rice husk</td>
<td>17.1 ± 0.3&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>28.0 ± 0.3&lt;sup&gt;c&lt;/sup&gt;</td>
<td>8.0 ± 0.8&lt;sup&gt;c&lt;/sup&gt;</td>
<td>33.3 ± 1.5</td>
<td>+ + + +</td>
</tr>
<tr>
<td>Corn cobs</td>
<td>23.2 ± 0.4&lt;sup&gt;c&lt;/sup&gt;</td>
<td>13.0 ± 0.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.0 ± 0.7&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.0 ± 0.0</td>
<td>+ + + + +</td>
</tr>
<tr>
<td>Rice straw</td>
<td>18.6 ± 0.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>27.0 ± 0.8&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.0 ± 1.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16.7 ± 1.2</td>
<td>+ + + +</td>
</tr>
<tr>
<td>Cassava peels</td>
<td>14.9 ± 1.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>31.0 ± 0.9&lt;sup&gt;ad&lt;/sup&gt;</td>
<td>2.0 ± 1.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0 ± 0.0</td>
<td>+ + +</td>
</tr>
<tr>
<td>Sawdust</td>
<td>23.0 ± 0.4&lt;sup&gt;c&lt;/sup&gt;</td>
<td>22.0 ± 0.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.0 ± 1.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0 ± 0.0</td>
<td>+ + + + +</td>
</tr>
</tbody>
</table>

Degree of mycelial density when the mycelia colonize the substrate (Obodai et al. 2003) with modifications.

- Nil - No growth
- + poor running growth,
- ++ mycelium grows throughout the whole bag but is not uniformly white,
- +++ mycelium grows throughout the whole bag and is uniformly white
- ++++ mycelium grows throughout the whole bag, uniformly white and thick

3.4 Contamination (%) and Mycelia density

There were significant differences (P<0.05) between level of contamination of substrate bags. Contaminations ranged between 0 - 33.3% (Table 2). The highest number of contaminations 33.3% was recorded by rice husk followed by 16.6% by both coconut coir and rice straw substrates. The rest of the substrates exhibited no contaminations and supported mycelia growth. Comparison of data with results from work of (Oseni et al, 2012), indicate that contamination was minimal.

3.5 Total number of primordia

There was significant variation (P<0.05) of the number of primordia recorded. The maximum number of 57 primordia
Table 3. Effect of gamma radiation of the different lignocellulose substrates on the Fruiting pattern of Pleurotus eous (P-31).

<table>
<thead>
<tr>
<th>Substrates</th>
<th>Total no. of primordia</th>
<th>Total no. of fruitbodies</th>
<th>Av. stipe length (mm)</th>
<th>Av. cap diameter (mm)</th>
<th>Mushroom size</th>
<th>Av. time b/n flushes (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconut coir</td>
<td>35 ± 0.20&lt;sup&gt;e&lt;/sup&gt;</td>
<td>29 ± 0.10&lt;sup&gt;e&lt;/sup&gt;</td>
<td>64 ± 0.11&lt;sup&gt;i&lt;/sup&gt;</td>
<td>62 ± 1.00&lt;sup&gt;h&lt;/sup&gt;</td>
<td>4.4</td>
<td>13 ± 0.23&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>Banana leaves</td>
<td>49 ± 0.15&lt;sup&gt;e&lt;/sup&gt;</td>
<td>47 ± 0.10&lt;sup&gt;e&lt;/sup&gt;</td>
<td>65 ± 0.11&lt;sup&gt;i&lt;/sup&gt;</td>
<td>76 ± 1.30&lt;sup&gt;h&lt;/sup&gt;</td>
<td>5.1</td>
<td>10 ± 0.22&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>Elephant grass</td>
<td>0 ± 0.00&lt;sup&gt;h&lt;/sup&gt;</td>
<td>0 ± 0.00&lt;sup&gt;h&lt;/sup&gt;</td>
<td>0 ± 0.00&lt;sup&gt;h&lt;/sup&gt;</td>
<td>0 ± 0.00&lt;sup&gt;h&lt;/sup&gt;</td>
<td>nil</td>
<td>0 ± 0.00&lt;sup&gt;h&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rice husk</td>
<td>38 ± 0.20&lt;sup&gt;e&lt;/sup&gt;</td>
<td>35 ± 0.20&lt;sup&gt;d&lt;/sup&gt;</td>
<td>61 ± 0.10&lt;sup&gt;e&lt;/sup&gt;</td>
<td>64 ± 0.11&lt;sup&gt;h&lt;/sup&gt;</td>
<td>3.9</td>
<td>15 ± 0.25&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>Corn cobs</td>
<td>52 ± 0.10&lt;sup&gt;f&lt;/sup&gt;</td>
<td>51 ± 0.11&lt;sup&gt;e&lt;/sup&gt;</td>
<td>80 ± 0.40&lt;sup&gt;i&lt;/sup&gt;</td>
<td>95 ± 0.09&lt;sup&gt;i&lt;/sup&gt;</td>
<td>6.5</td>
<td>9 ± 0.57&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rice straw</td>
<td>42 ± 0.75&lt;sup&gt;e&lt;/sup&gt;</td>
<td>38 ± 0.20&lt;sup&gt;d&lt;/sup&gt;</td>
<td>63 ± 0.10&lt;sup&gt;e&lt;/sup&gt;</td>
<td>65 ± 0.10&lt;sup&gt;h&lt;/sup&gt;</td>
<td>4.9</td>
<td>10 ± 0.22&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cassava peels</td>
<td>39 ± 0.20&lt;sup&gt;e&lt;/sup&gt;</td>
<td>36 ± 0.20&lt;sup&gt;d&lt;/sup&gt;</td>
<td>61 ± 0.10&lt;sup&gt;e&lt;/sup&gt;</td>
<td>65 ± 0.10&lt;sup&gt;h&lt;/sup&gt;</td>
<td>4.7</td>
<td>12 ± 0.24&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sawdust</td>
<td>57 ± 0.10&lt;sup&gt;f&lt;/sup&gt;</td>
<td>51 ± 0.12&lt;sup&gt;e&lt;/sup&gt;</td>
<td>58 ± 0.09&lt;sup&gt;i&lt;/sup&gt;</td>
<td>64 ± 0.11&lt;sup&gt;h&lt;/sup&gt;</td>
<td>6.5</td>
<td>14 ± 0.24&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Means with same letters in a column are not significantly different (P>0.05)

The maximum number of mushrooms produced per flush was 110g (Table 4) from corn cobs. The minimum number of mushrooms per flush was 0g from elephant grass. Generally, production decreased with increasing flush numbers (Owusu-Boateng and Dzogbefia, 2005). This could be attributed to lignocelluloses depletion and accumulation of metabolites in the substrate (Kortei, 2008).

3.10 Growth and Yield attributes

The total fresh weight of mushrooms or economical yield is the proportion of fresh mushrooms to wet weight of substrate. It was recorded from 4 flushes of cropping period. Statistically, there were significant (P<0.05) variations in the total fresh weights or economical yield of different lignocelluloses due to their different carbon and nitrogen contents. The maximum total fresh weight was 377 g recorded from corn cob substrate (Table 4). The highest yield appeared to be due to comparatively better availability of nitrogen, carbon and minerals from this substrate (Shah et al, 2004; Youri, 2004). The minimum total fresh weight of mushrooms or mushroom yield was 0g recorded by elephant grass (Table 4). Elephant grass presumably possesses a lignin, cellulose and hemicelluloses proportion which might be disadvantageous to oyster mushrooms. Generally, irradiated lignocelluloses substrates produced comparable yields of works by several researchers (Obodai et al, 2003; Mondal et al, 2010; Nge’tich, 2013).

3.11 Total fresh weight/ Economical yield

The total biological efficiency refers to the measure of total fresh weight to the dry weight of substrate. There were significant differences (P<0.05) in bio-yield with respect to the various treatments. Hence the biological efficiency is expressed as a percentage of the proportion. Stemets, (2000) indicated that biological efficiency is achieved by a 25% conversion of moist substrate to fresh mushrooms. The maximum biological yield and efficiency of 0.63 kg/kg of dry substrate weight and 63.2%
respectively was recorded by irradiated corn cob substrate (Table 4). The minimum biological yield and efficiency (0g per flush, 0%) recorded by irradiated elephant grass. The biological yield and efficiency of these substrates were within the range of works by several researchers (Obodai et al, 2003; Mshandete et al, 2011; Hasan et al, 2010; Narh et al, 2011). However, Baig et al, (2009) reported greater values when they investigated the biological efficiencies and nutritional contents of *P. florida* on different agro wastes.

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Flush (g)</th>
<th>Total yield/ Mush. yield</th>
<th>Biol. Yield g/g subt.</th>
<th>B.E (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconut coir</td>
<td>58±0.03</td>
<td>153±0.25</td>
<td>0.26</td>
<td>26</td>
</tr>
<tr>
<td>Banana leaves</td>
<td>102±0.04</td>
<td>325±0.1</td>
<td>0.54</td>
<td>54</td>
</tr>
<tr>
<td>Elephant grass</td>
<td>nil</td>
<td>nil</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>Rice husk</td>
<td>79±0.16</td>
<td>193±0.02</td>
<td>0.32</td>
<td>33</td>
</tr>
<tr>
<td>Corn cobs</td>
<td>110±0.07</td>
<td>377±0.05</td>
<td>0.62</td>
<td>63</td>
</tr>
<tr>
<td>Rice straw</td>
<td>66±0.06</td>
<td>230±0.5</td>
<td>0.38</td>
<td>38</td>
</tr>
<tr>
<td>Cassava peels</td>
<td>81±0.08</td>
<td>272±0.5</td>
<td>0.45</td>
<td>45</td>
</tr>
<tr>
<td>Sawdust</td>
<td>103±0.04</td>
<td>368±0.06</td>
<td>0.61</td>
<td>61</td>
</tr>
</tbody>
</table>

Means with same letters in a column are not significantly different (P>0.05)

Nil - No growth

4. CONCLUSION

The results of this study revealed that gamma irradiation could be used as an alternative method for the pretreatment of lignocellulose agro-wastes substrates for mushroom cultivation for countries and sub regions that have access to gamma radiation facility.

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References


