ORIGINAL SCIENTIFIC PAPER

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 23.2mm/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 95mm for cap diameter, 80mm for stipe length, 52 for number of primordia, 51 for number of fruit bodies, 6.5 for mushroom size and 9days for time between flushes. The biological efficiency (B.E %) was 63%, mushroom yield was 377g 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
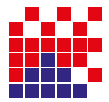
1. INTRODUCTION

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.(Phillippousis 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 precincts 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; Martín and Thomsen, 2007), few reports exist on the use of gamma irradiation (Martfnez 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).

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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 (Tuttlingten™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 105 °C to ensure that the steamed grains were cooked but intact. 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 dried in the sun for 2 hours. Each substrate with average moisture content 30% (w/w) (88 parts) was thoroughly mixed with 11.5parts rice bran and 0.5 part of calcium oxide. Water was sprinkled on the mixture until its moisture content was about 70% (w/w). The mixture was piled up into a pyramidal heap and allowed to ferment for 14days. It was turned every four days to ensure proper aeration and homogeneity. Aliquots of composted substrates (1 kg) were bagged into 33 x 18 cm²

heat-resistant, 0.1 *μ*m polypropylene bags (Auetrugal, 1984). Sawdust substrate was prepared by composting for 28 days and bagged as described above.

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

Fruit primordia were allowed to develop to mature fruiting bodies and were picked. Mushrooms were harvested by grasping the base of the stalk and pulling them by hand from the substrate, then were taken away for weighing the same day. The oyster mushrooms were harvested when the in–rolled margins of the basidiophores began to flatten (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

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

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 previous 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 wet weight of substrates - 1000 g/ 1 kg. A Digital Computing Scale (Hana Electronics Company Limited, Korea) was used to take all weight measurements and the unit for measurement was in grams (g).

2.9 Statistical Analysis

All experiments were performed in 4 replicates. The data on mycelium run, mushroom size, mushroom yield, and biological efficiency of *Pleurotus ostreatus*, cultivated on the pretreated gamma radiation substrates were subjected to analyses of variance (one-way ANOVA) when significant differences were determined post-hoc test were made using Duncan's multiple range test i.e. DMRT (Gomez and Gomez, 1984) with SPSS 16 (Chicago, USA).

3. RESULTS AND DISCUSSIONS

Influence of gamma radiation on the physical properties of eight lignocellulose materials and the effect on the mycelia growth of *P.eous* (P-31) are shown in Table 1. The pH of the substrates ranged from 5.34±0.08 - 6.13±0.08 for rice straw and cassava peels respectively. Generally, there were significant differences (P<0.05) between the treatments. The pH values fell within the range of slightly acidic. Some scientists reported that optimum pH ranges are mainly related to different species, strains, enzymatic systems, important vitamin entry in the cell, mineral capture, and surface metabolic reactions (Hung and Trappe, 1983; Barros et al, 2006). The pH values obtained were within the optimal pH range for growth of *P. ostreatus* (Martinez-Carrera, 1998; OECD, 2005) hence their ability to support good mycelia growth. The temperature also ranged 23.55±1.50 - 24.50±1.50. Temperatures were conducive to support growth of microorganisms.

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 *P.eous*. Nutritional composition of substrates has been reported to be crucial in determining how mycelia growth initiation occurs (Stamets, 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'tich 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 *P.eous* mycelia (Kortei, 2008). Obodai et al, (2003) observed no mycelia growth on elephant grass as they studied the growth and yield of *P.ostreatus* 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
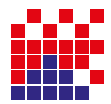
Table 2. Effect of gamma radiation on P.eous (Berk.) Sacc. Strain P-31 mycelia growth on eight lignocellulose agro-wastes

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

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

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

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 substrate which caused anaerobic conditions and temperature build up (Recycled Organics, 2003). Shah et al (2004), observed that variation in mycelia growth with substrates could be due to their difference in nutrient composition. These results agreed with findings of Kortei, (2008) when he investigated *P.ostreatus* mycelia growth on cassava peel and corn cob based formulations.

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 quick maturity of the mycelia (Betiku et al, 2010). The shortest time of 2 days (Table 2) taken for the appearance of primordial was recorded by rice straw, cassava peels and sawdust. It is noteworthy that corncobs which recorded the overall best mycelia attributes, rather recorded the longest time of 10 days (Table 2) for primordial emergence which is suggestive of inadequate environmental conditions to stimulate primordial formation.

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.

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 contamination of substrate bags.

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. This result could be attributed to unfavorable physical conditions as pH, temperature, anaerobic conditions and presence of metabolites from the other microorganisms which inhibited mycelia growth.

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).

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

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

was recorded by irradiated sawdust (Table 3). The minimum was 0 primordia were recorded by elephant grass. Thriving primordia ultimately becomes fruit bodies, if there is a balance of carbon to nitrogen (C:N) ratio (Hubbe et al, 2010). Results obtained were comparable to results of (Mshandete, 2011; Raymond et al, 2011)

3.6 Total fruit bodies

The maximum fruit bodies recorded was 51 by irradiated sawdust and corn cobs (Table 3). The minimum number of 0 fruit bodies was recorded by irradiated elephant grass. Total number of fruit bodies showed significant differences (P<0.05).

3.7 Cap diameter and Stipe length

The longest cap diameter and stipe length of 95mm and 80 mm respectively were recorded on irradiated corncobs substrate (Table 3). The shortest cap diameter and stipe lengths 0mm and 0mm respectively were recorded from irradiated elephant grass (Table 3). There were significant differences (P<0.05) recorded. Averagely, the ranges were in agreement with works (Nurudeen et al, 2013; Raymond et al, 2013; Mshandete, 2010; Kortei, 2008; Owusu-Boateng and Dzogbefia, 2005)

3.8 Mushroom size

According to researchers (Reyes et al, 2009; Kurtzman, 2010), interactions between environmental factors and nutrients in mushroom growth substrate have been reported to play important role in inducing formation of the fruiting bodies which results in mushroom size variations. Maximum and minimum mushroom sizes of 6.5 and 0.0 were recorded by combination as in cap diameter and stipe lengths (Table 3). Mushroom sizes differed significantly (P<0.05) and were with the range reported by Raymond et al, (2013).

3.9 Interval between flushes

Flush refers to a batch of mushrooms maturing at a particular time. Mushrooms are harvested usually in 7-10 days interval (Table 3). Nevertheless, such an interval is influenced by various factors such as level of spawn, quantity of substrate and crop management (Amin et al, 2008; Adabayo et al, 2009).

The average time ranged between 0 - 15 days (Table 3). Results were greater than published data of researchers (Mshandete, 2011; Raymond et al, 2013).

3.10 Growth and Yield attributes

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).

3.11 Total fresh weight/ Economical yield

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 lignocellulose materials 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 lignocellulose substrates produced comparable yields of works by several researchers (Obodai et al, 2003; Mondal et al, 2010; Nge'tich, 2013).

3.12 Biological Efficiency, Bio-yield

The biological yield 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. Stamets, (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%
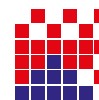
Table 4. *Effect of gamma radiation on the different lignocellulose substrates and the yield pattern of Pleurotus eous (P-31)*

Substrate	Flush(g)				Total yield/ Mush. yield	Biol. Yield g/g subt.	B.E (%)
	1	2	3	4			
Coconut coir	58±0.03	54±0.05	41±0.03	nil	153±0.25[a]	0.26	26
Banana leaves	102±0.04	93±0.07	72±0.04	58±2.25	325±0.1[de]	0.54	54
Elephant grass	nil	nil	nil	nil	nil	nil	nil
Rice husk	79±0.16	65±0.04	49±2.27	nil	193±0.02[a]	0.32	33
Corn cobs	110±0.07	98±0.08	89±0.08	80±0.04	377±0.05[f]	0.62	63
Rice straw	66±0.06	53±0.21	52±0.04	59±1.90	230±0.5[d]	0.38	38
Cassava peels	81±0.08	75±0.04	69±1.90	47±2.27	272±0.5[d]	0.45	45
Sawdust	103±0.04	98±0.08	87±0.05	80±0.05	368±0.06[f]	0.61	61

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

Nil - No growth

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.

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.

Acknowledgement

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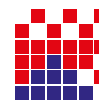
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