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Oyster Mushroom Cultivation on Water Hyacinth Biomass: Assessment of Yield Performances, Nutrient, and Toxic Element Contents of Mushrooms

Sunita Bandopadhyay Mukhopadhyay

Abstract

To obtain a cost-effective production of oyster mushrooms, invasive aquatic weed water hyacinth has been tried out as a substrate in different combinations with rice straw (1:1, 1:2, 2:1) for the cultivation of *Pleurotus* species. The yield of mushrooms significantly increases with their 1:1 combination (RS + WH 1:1), especially in the first flush. No significant differences are observed between the nutrient qualities of the oyster mushrooms that grow either on rice straw or on water hyacinth supplemented rice straw (1:1). Minerals (Fe, Cu, Zn) and toxic elements (Pb, Cd, As) though flow from the substrate of RS + WH (1:1) to the mushrooms do not accumulate at a toxic level. The results of the present study indicate that biomass of water hyacinth weed can safely be used with rice straw (1:1) as the alternate substrate for the cultivation of *Pleurotus* species to reduce the cost of production of protein-rich oyster mushroom and to recycle the vast amount of nuisance weed in an eco-friendly way.

Keywords: oyster mushroom cultivation, *Pleurotus florida*, *P. citrinopileatus*, *P. pulmonarius*, aquatic weed, water hyacinth, biological yield, nutrient quality, mineral, toxic elements

1. Introduction

The fruit bodies of the genus *Pleurotus* are generally referred to as 'oyster mushroom.' It is a lignocellulolytic fungus of Basidiomycetes and grows naturally in the temperate and tropical forests [1] on dead and decaying wooden logs, sometimes on dying trunks of deciduous or coniferous woods or decaying organic matter. It is one of the most suitable fungal organisms for producing protein-rich food (mushroom) from various agricultural or forest wastes without composting.

Cultivation of oyster mushroom (*Pleurotus* spp.) has increased greatly throughout the world during last few decades due to the ease of its cultivation on various lignocellulosic wastes, shorter growth time, no need of composting of its substrate, demand for a few environmental control, high yield potential, high nutritional

values as well as medicinal values. These features make oyster mushroom cultivation suitable for the beginners and the mushroom farmers with low-tech equipment. The other reason for the great interest in species of *Pleurotus* is that they secrete a wide range of enzymes [2, 3] capable of degrading lignocellulosic biomass. They are therefore capable of growing on a wide range of substrates. Furthermore, some species grow and fruit at a relatively high temperature, a feature that makes for lower production costs in tropical or subtropical areas, or even in temperate regions during the summer season. Due to these advantages of oyster mushroom, many researchers have been striving to make use of different weeds for example, *Typha* sp. [4], *Leonotis* sp., *Sida acuta*, *Parthenium argentatum*, *Ageratum conyzoides*, *Cassia sophera*, *Tephrosia purpurea*, and *Lantana camara* [5, 6] as the substrates for cultivation of *Pleurotus* species with the concept of eradication through utilization [7–9] and cost-effective production of mushroom. The main problem in the cultivation of *Pleurotus* spp. on weed biomass, is their low yield, especially from the second flush. This problem could be overcome by blending weed plants with other commonly used lignocellulosic wastes like rice straw, wheat straw, or sawdust.

Water hyacinth [*Eichhornia crassipes* (Mart.) Solms.], a fast-growing aquatic weed in tropics and sub-tropics causes serious ecological and economic problems by choking water bodies. On the other hand, it has drawn attention as a plant capable of removing toxic heavy metals (e.g., Cr, Cd, Ni, As, Pb, Eu) from wastewater by adsorbing them on its root and is being used in wastewater treatment [8, 10, 11]. Utilization of the vast quantities of this weed available throughout the year, as a low-cost substrate for oyster mushroom cultivation has been reported by several workers [12–14]. But, the information regarding the effect of this weed on the nutritional qualities and the heavy metal bioaccumulation in the harvested oyster mushrooms is not sufficient. Growing up on a substrate contaminated with various toxic elements may cause edible mushrooms to accumulate those elements at higher concentrations [2], as many mushroom species are known to be efficient accumulators of trace elements [15]. Analysis of concentrations of essential mineral elements and non-essential toxic elements (e.g., As, Pb, Cd, Hg) allows the evaluation of the nutritional quality and health risk of food and is thus part of every food safety program. Therefore, as a prerequisite to assess the contribution of these undesirable elements to the dietary intake as per norms of the food safety program, it is worthwhile to evaluate their levels in the mushrooms grown (artificially/naturally) on any substrate and also to report any possible contamination that would represent a health hazard.

Taking stock of the above needs to assess the feasibility of utilizing water hyacinth as a substrate for cost-effective production of oyster mushrooms, the present chapter highlights the study on (i) the biological yields of three species of *Pleurotus* viz., *Pleurotus florida*, *P. citrinopileatus*, and *P. pulmonarius* cultivated separately on different combinations of rice straw and water hyacinth; (ii) the important biochemical and nutrient qualities of the harvested oyster mushrooms; and (iii) the concentrations of mineral elements (Fe, Cu, Zn) and toxic elements (Pb, Cd, As) in the substrate of cultivation as well as in the harvested mushrooms. The study also attempts to assess the contribution of consumption of these oyster mushrooms to the recommended dietary allowances (RDA) or provisional tolerable daily intake set for mineral elements and toxic elements by standard expert council or committee as The National Academies [16], FAO/WHO [17] or Codex Alimentarius [18] of food safety program. The chapter finally summarizes the findings to conclude the feasibility of utilizing the nuisance weed as the low-cost supplement to rice straw for higher yield of oyster mushrooms, which can be consumed safely.

2. Materials and methods

2.1 Cultivation of *Pleurotus* species

2.1.1 Mushroom strains

Three species of *Pleurotus* namely *Pleurotus florida nomen nudum* (Eger), *P. citrinopileatus* Sing., and *P. pulmonarius* (Fr.) Quel., procured from National Center for Mushroom Research and Training (NCMRT), Solan, Himachal Pradesh, India are used for cultivation. The cultures are maintained on Potato-Dextrose-Agar slants and during the period of cultivation, spawns of the mushroom species are prepared with intact wheat grains [19] in autoclavable polypropylene bags (15 × 12 cm).

2.1.2 Substrate

Rice straw (RS) and sun-dried water hyacinth (WH) plants are used as a substrate for the cultivation of *Pleurotus* spp. WH plants are collected locally from the banks of ponds, lakes, and rivers after cleaning of the water bodies. The roots are discarded (as reported to adsorb heavy metals) from the sun-dried plants to use in the preparation of mushroom beds.

2.1.3 Preparation of substrates and cultivation of mushroom

Cultivation trials are conducted at different temperature regimes (different seasons of the year) on five separate combinations of RS and WH (wet weight/wet weight) viz., (i) only RS, (ii) only WH, (iii) RS + WH (1:1), (iv) RS + WH (2:1), and (v) RS + WH (1:2). Both the substrates (RS and WH) are pretreated and the mushroom beds are prepared by packing the substrates in the transparent polythene bags [20]. The beds are then inoculated with 5% (w/w on the wet weight basis) grain spawn of the *Pleurotus* spp. by the layer spawning method [19]. After spawn run (mycelial colonization of the substrate) at $25 \pm 2^\circ\text{C}$ and $65 \pm 5\%$ relative humidity in the semi-dark condition, fruit body formation is triggered by shifting the environmental variables namely moisture, air exchange, temperature, and light in the cropping room [19]. Fruit primordia (pinhead) are developed within a temperature and relative humidity regimes of $22\text{--}30^\circ\text{C}$ and $70\text{--}75\%$, respectively, for the moderate temperature requiring species of *P. citrinopileatus* and *P. pulmonarius*. The low-temperature requiring species of *P. florida* fructify at $14\text{--}22^\circ\text{C}$ and $75\text{--}80\%$ relative humidity. Mushrooms are harvested manually from each bed when the pinheads are developed to complete fruit body and weighed the same day. The beds are maintained until the harvest of third flush. Production of mushrooms per flush is recorded only at respective optimum temperature regimes (favorable season) of each species to calculate the biological yield per flush [biological yield (B.Y.) = weight of fresh mushrooms harvested (g) per kg dry substrate]. The distribution of the yield (B.Y.) of the experimental species of *Pleurotus* is tabulated to observe any change in the yield over three flushes.

2.2 Nutrient and biochemical qualities of the mushrooms

For proximate analysis of important nutrient and biochemical properties, the mushrooms of each species of *Pleurotus* are harvested from the beds of RS and RS + WH (1:1) separately, oven-dried at 60°C for 72 h and milled to obtain samples of oyster mushrooms (dry weight biomass or DWB). The moisture content of the

fresh mushrooms and the total protein (modified Lowry's method), total carbohydrate, vitamins (ascorbic acid and niacin), reducing sugar, crude fiber contents in the DWB are estimated following Sadasivam and Manikam [21]. Exchangeable potassium (by flame photometry method), water-soluble cations (Na^+ , K^+ , Ca^+) (through ion-exchange chromatography; Metrohm 861 Advanced Compact IC), ash contents, electrical conductivity (EC) and pH in the mushroom samples (DWB) are determined by the methods of Rao and Reddy [22]. Total soluble salt concentration is calculated from EC [21].

2.3 Essential mineral and toxic element contents in the mushrooms and the substrate (RS + WH 1:1) before cultivation

Iron, copper, and zinc (Fe, Cu, Zn), the essential trace elements for human, have been chosen as representative essential minerals and lead, cadmium, arsenic (Pb, Cd, As) as representative toxic elements, whose levels in environment represent a reliable index of environment pollution. Concentrations of these representative minerals and toxic elements in the mushrooms harvested from RS + WH (1:1) beds and in the respective substrates (before cultivation) are determined [23] with atomic absorption spectrometer (AAS) [Perkin Elmer 5100 PC for Cu, Zn, Fe, Pb, and Cd; AVANTA GBC AAS with flamed hollow cathode lamp for As]. Samples of mushroom are prepared by mixing the dry mushrooms of the three species of *Pleurotus* in equal proportions (by weight) and used for AAS estimation after their acid digestion [24]. The concentrations of all the essential mineral and toxic elements are the mean of three replicates and expressed in mg per kg dry weight biomass (mg/kg DWB) of mushroom or substrate.

2.4 Statistical analysis

The experiments on cultivation are laid out in a completely randomized design with five combinations of substrates and three species of *Pleurotus*. All the experiments are performed in triplicates and the data are analyzed using descriptive statistics and also subjected to ANOVA to ascertain any significant difference (at $P \leq 0.05$ for yield and at $P \leq 0.01$ for nutrient qualities) between treatments. Least significant differences (LSD) between the means of biological yields are calculated for the *Pleurotus* spp. [25].

3. Results and discussion

3.1 Yield performances of *Pleurotus* species

Among the three species of *Pleurotus*, *P. citrinopileatus* produces the highest number of fruit bodies per mushroom bed, but the maximum size and weight of the individual fruit body are obtained from *P. florida* (maximum size 22 cm x 17 cm, maximum weight-105 g). Mushroom beds with 1:1 and 1:2 combinations of rice straw and water hyacinth show a faster rate of spawn run, pinhead initiation and earlier harvest of mushroom than other combinations.

Table 1 represents the distribution of the yield (B.Y.) of the three *Pleurotus* species during the period of three flushes on five different combinations of substrates. A perusal of the yield performances (**Table 1**) shows a significant increase in B.Y. of each species on the 1:1 combination of rice straw and water hyacinth (RS + WH 1:1) especially, in the first flush. Although the total yields (g/kg DWB

| Substrate combination | Biological yield* (g fresh weight of mushroom/kg dry weight of substrate) of <i>Pleurotus</i> spp. | | | | | | | | |
|-----------------------|--|-----------|-----------|---------------------------|-----------|-----------|-----------------------|-----------|-----------|
| | Species of oyster (<i>Pleurotus</i>) mushroom | | | | | | | | |
| | <i>P. florida</i> | | | <i>P. citrinopileatus</i> | | | <i>P. pulmonarius</i> | | |
| | 1st flush | 2nd flush | 3rd flush | 1st flush | 2nd flush | 3rd flush | 1st flush | 2nd flush | 3rd flush |
| Rice straw (RS) | 581 ± 142 | 504 ± 84 | 185 ± 50 | 617 ± 45 | 575 ± 21 | 485 ± 15 | 558 ± 60 | 422 ± 46 | 260 ± 56 |
| Water hyacinth (WH) | 606 ± 176 | 350 ± 14 | 190 ± 10 | 607 ± 145 | 567 ± 15 | 37 ± 42 | 624 ± 47 | 347 ± 10 | 168 ± 25 |
| RS + WH (1:1) | 716** ± 373 | 489 ± 172 | 215 ± 111 | 721** ± 63 | 505 ± 148 | 408 ± 226 | 679** ± 32 | 522 ± 182 | 278 ± 30 |
| RS + WH (1:2) | 608 ± 270 | 498 ± 95 | 232 ± 31 | 633 ± 10 | 387 ± 10 | 18.6 ± 10 | 608 ± 31 | 435 ± 33 | 212 ± 35 |
| RS + WH (2:1) | 550 ± 98 | 540 ± 70 | 230 ± 28 | 610 ± 84 | 514 ± 35 | 325 ± 21 | 550 ± 28 | 340 ± 70 | 285 ± 50 |
| LSD at 5% level | 121.1 | 79.4 | 43 | 60.1 | 24.6 | 77 | 50.3 | 76.3 | 39.1 |

*Results are mean ± standard deviation.
 **Results are significantly different ($P \leq 0.05$) from yields on RS.

Table 1. Biological yield of *Pleurotus* spp. upto third flush on five combinations of rice straw (RS) and water hyacinth (WH).

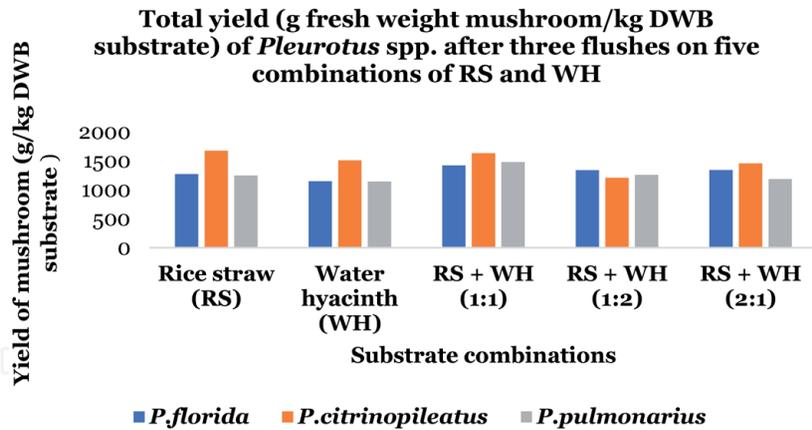


Figure 1. Total yield of mushrooms (g/kg DWB of substrate) of each of the three species of *Pleurotus* after three flushes on each of the five substrate combinations.

substrate) after three flushes of *P. citrinopileatus* (1634 g/kg), *P. pulmonarius* (1479 g/kg), and *P. florida* (1421 g/kg) (Figure 1) on RS + WH (1:1) do not differ significantly. Supplementation of wheat straw with water hyacinth [4] or supplementation of rice straw with different weeds [5] has been reported to increase the yield of mushrooms. Though the negative effect of the weed on the yield of *P. sajor-caju* has also been reported [26]. The better yield with water hyacinth may be due to mitigation of optimal nutritional requirements of mushroom fungi, better aeration and water retention capacity to the mushroom beds by aquatic spongy plant water hyacinth over rice straw up to the stage of fruit body formation. Moreover, supplementation of nitrogen by natural nitrogen-rich supplement as

water hyacinth may have resulted in a higher rate of lignocellulolytic degradation. In all the subsequent experiments and analyses of this study, the mushrooms grown on the beds of RS + WH (1:1) are, therefore, taken into consideration for quality assessment.

3.2 Assessment of nutrient quality of mushroom

Comparisons of important nutrient qualities of *Pleurotus* mushrooms harvested from the beds of RS and RS + WH (1:1) reveal no significant differences (**Table 2**) except EC (electrical conductivity). The total protein content of the mushroom varies from 16 to 25% (on the dry weight basis) among the three species of *Pleurotus* (**Table 3**), which are higher than the earlier reports [12] on *P. sajor-caju*. Previous workers have reported protein content ranging from 3 to 5% on the dry weight basis (in *P. florida*, *P. sajor-caju*, and *P. eous*) [27] and from 0.5 to 1% on the fresh weight basis (in *P. ostreatus*) [5] of the oyster mushrooms cultivated on different weeds. The total carbohydrate content of the experimental mushrooms ranges between 19 and 28% (DWB), which is lower than those reported earlier [12, 27]. The vitamin contents of the mushrooms are higher than the earlier reports [12] on *Pleurotus* spp. The crude fiber and the ash contents of the mushrooms are approximately similar to previous findings on *P. sajor-caju* [12]. Electrical conductivity (EC) and as such total soluble salt concentration (calculated from EC) are found to be significantly higher in mushrooms from RS + WH (1:1), which complies with the previous findings [12] in *P. sajor-caju*. The available K⁺ content in mushrooms grown on RS + WH (1:1)

| Nutrient qualities | Nutritional values* of mushrooms grown on | |
|---------------------------------------|---|-----------------|
| | RS | RS + WH (1:1) |
| Moisture (% FWB) | 79.3 ± 11.7 | 82.7 ± 8.1 |
| Protein (% DWB) | 19.2 ± 2.6 | 22.2 ± 2.7 |
| Carbohydrate (% DWB) | 26.5 ± 1.9 | 22.9 ± 1.7 |
| Vitamins | | |
| (i) Ascorbic acid (% DWB) | 0.0133 ± 0.0003 | 0.0123 ± 0.0002 |
| (ii) Niacin (% DWB) | 0.0022 ± 0.0001 | 0.0013 ± 0.0006 |
| Reducing sugars (% DWB) | 3.9 ± 1.3 | 4.4 ± 1.2 |
| Crude fiber (% DWB) | 9.1 ± 0.3 | 9.4 ± 0.5 |
| Ash (% DWB) | 18.5 ± 1.5 | 18.4 ± 0.7 |
| Exchangeable K ⁺ (% DWB) | 5.1 ± 0.06 | 4.4 ± 0.07 |
| Water soluble K ⁺ (% DWB) | 0.13 ± 0.05 | 0.18 ± 0.06 |
| Water soluble Na ⁺ (% DWB) | 0.04 ± 0.04 | 0.05 ± 0.04 |
| Water soluble Ca ⁺ (% DWB) | 0.01 ± 0.005 | 0.01 ± 0.004 |
| EC (electrical conductivity) (mS/cm) | 1.5 ± 0.4 | 2.1 ± 0.2** |
| pH | 6.9 ± 0.3 | 6.0 ± 0.2 |

FWB = fresh weight biomass; DWB = dry weight biomass of mushroom.

*Results are mean ± standard deviation.

**Results are significantly different ($P \leq 0.01$).

Table 2.

Comparisons of nutrient and biochemical qualities of oyster mushrooms (*Pleurotus* spp.) grown on rice straw (RS) and water hyacinth supplemented rice straw (RS + WH 1:1).

| <i>Pleurotus</i> spp. | Moisture | Protein | Total soluble salt |
|---------------------------|--|--|--------------------|
| | % of fresh weight biomass of mushroom (% FWB)* | % of dry weight biomass of mushroom (% DWB)* | |
| <i>P. florida</i> | 84.9 ± 10 | 23.8 ± 1.3 | 0.5 ± 0.7 |
| <i>P. citrinopileatus</i> | 81 ± 7 | 20.8 ± 0.8 | 0.7 ± 0.5 |
| <i>P. pulmonarius</i> | 82 ± 8 | 16.8 ± 1.3 | 0.6 ± 0.4 |

*Results are mean ± standard deviation.

Table 3. Moisture, protein and total soluble salt contents of mushrooms of three spp. of *Pleurotus* cultivated on RS + WH (1:1).

exceeds the values in earlier reports [12] for different *Pleurotus* species. But as the recommended dietary allowance (RDA) of potassium is 4.7 g/day/person [16], so these mushrooms (fresh weight) are safe for daily consumption. **Table 3** indicates no significant variation among the experimental mushroom species (*P. florida*, *P. citrinopileatus*, and *P. pulmonarius*) in their moisture, total protein and, total soluble salt contents.

3.3 Assessment of mushroom quality based on the levels of important mineral and toxic elements

Table 4 depicts the concentrations (mg/kg DWB) of representative essential minerals (Fe, Zn, and Cu) and non-essential toxic metals (Pb, Cd, and As) in the harvested mushrooms as well as in their respective substrates (RS + WH 1:1) before cultivation. The results are consistent with the previous studies on cultivated mushrooms and except arsenic [24], fall within the range reported for *Pleurotus* mushrooms in the literature [24, 28–31].

| Mineral/toxic element | Concentration** (mg/kg DWB* of substrate) of mineral and toxic element in the substrate (RS + WH 1:1) before cultivation | Concentration** (mg/kg DWB* of mushroom) of mineral and toxic element in the mushrooms of the present study | Range of mineral and toxic element contents in cultivated spp. of <i>Pleurotus</i> in published literature (mg/kg DWB* of mushroom) | References |
|-----------------------|--|---|---|--------------|
| Iron (Fe) | 295 ± 104.3 | 216 ± 92.3 | 67–1524 | [24, 28–30] |
| Zinc (Zn) | 56.5 ± 6.2 | 53.1 ± 5 | 54–180 | [28–30] |
| Copper (Cu) | 11.9 ± 2.6 | 12.1 ± 0.9 | 11–182 | [28–30] |
| Lead (Pb) | 7.2 ± 1.2 | 2.2 ± 1.1 | n.d.–4.4 | [28, 29, 31] |
| Cadmium (Cd) | 2.7 ± 1.8 | 1.8 ± 0.8 | 0.3–2.9 | [24, 28–30] |
| Arsenic (As) | 3.4 ± 0.06 | 0.5 ± 0.3 | 0.04 | [24] |

*DWB = dry weight biomass.

**Results are mean ± SD.

Table 4. Concentrations (mg/kg) of minerals and toxic elements in the mushrooms and respective substrate before cultivation (RS + WH 1:1) in the present study and the range of their concentrations in selective references.

3.3.1 Bioaccumulation factor

The bioaccumulation factor represents the element concentration in mushrooms compared with its concentration in the environment (in soil/substrate) [32]. The ability of mushrooms to accumulate elements from the substrates [15] is expressed by a bioaccumulation factor or co-efficient of accumulation (K_a), which is the ratio of the concentration (on the dry weight basis) of an element in the mushrooms (C_m) to the concentration (on the dry weight basis) in the underlying substrate (C_s) ($K_a = C_m/C_s$). K_a of the representative elements in the studied mushrooms are presented in **Table 5**, which shows the bioaccumulation factor in the descending order of $Cu > Zn > Fe > Cd > Pb > As$. This indicates higher mobility of copper than the zinc or iron in the analyzed species of mushrooms. Lead and arsenic are accumulated at minimal levels. The bioaccumulation factor for lead decreases as its concentrations in substrate increases. Thus, the studied oyster mushroom has probably a regulative mechanism for lead intake. Similar findings have been reported in the literature for cadmium uptake in *Pleurotus ostreatus* [15]. Levels of the undesirable metals are considerably lower in the cultivated mushrooms than in the same or taxonomically-related wild-growing species [15]. For a plant or mushroom to be efficient bio-accumulator, the bioaccumulation factor has to be higher than one [32]. Therefore, it is obvious that in the present study although the toxic elements are present in the initial substrates of cultivation (water hyacinth supplemented rice straw 1:1), but are not accumulating at toxic levels in the mushrooms.

3.3.2 Contribution of the mushroom consumption to the dietary intake

In order to contribute to the safe consumption of the experimental mushrooms (grown on RS + WH 1:1) to the dietary intake of essential minerals and to evaluate the risk of dietary exposure to the toxic elements, the concentrations of the representative elements are compared with the recommended values of dietary intake for an average adult of 60 kg body weight (b.w.) set by standard international organizations [16–18]. As the recommended values are based on the fresh weight of mushroom, the mineral and toxic element contents (on the dry weight basis) are converted on the scale for 100 g fresh mushroom (considering 82 % average moisture content of the experimental mushrooms) and presented in **Table 6**. The concentrations of Fe, Zn, Cu, Pb, Cd, and As are found to be approximately

| Mineral/toxic element | Concentration of mineral/toxic element (mg) in the mushrooms produced per kg DWB of substrate (considering 82% moisture content of the mushrooms) (C_m) | Concentration of mineral and toxic element (mg) per kg DWB of substrate (rice straw + water hyacinth 1:1) (C_s) | Bioaccumulation factor or coefficient of accumulation ($K_a = C_m/C_s$) |
|-----------------------|---|---|---|
| Iron (Fe) | 61.6 | 295 | 0.21 |
| Zinc (Zn) | 15.1 | 56.5 | 0.26 |
| Copper (Cu) | 3.4 | 11.9 | 0.28 |
| Lead (Pb) | 0.62 | 7.2 | 0.09 |
| Cadmium (Cd) | 0.51 | 2.7 | 0.19 |
| Arsenic (As) | 0.14 | 3.4 | 0.04 |

Table 5. Bioaccumulation factor (K_a) of the mineral and toxic elements in the mushrooms produced on RS + WH (1:1).

| Mineral/toxic element | Recommended values of dietary intake (derived from RDA ^a , ^b /PTWI ^{**} , ^c) mg/day/person | Mineral/toxic element content (mg) per 100 g fresh weight of experimental mushroom |
|-----------------------|---|--|
| Iron (Fe) | 8/18 (male/female) ^a | 3.8 |
| Zinc (Zn) | 11/8 (male/female) ^a | 0.95 |
| Copper (Cu) | 0.9 ^a | 0.21 |
| Lead (Pb) | 0.2 ^b | 0.04 |
| Cadmium (Cd) | 0.06 ^b | 0.03 |
| Arsenic (As) | 0.12–0.42 ^c | 0.009 |

^{*}RDA, recommended dietary allowances.
^{**}PTWI, provisional tolerable weekly intake.
^aReferred to National Research Academies, 2006 [16].
^bCodex Alimentarius, 2011 [18].
^cJoint FAO/WHO expert committee, 2010 [17].

Table 6.
 Recommended dietary intake (mg/day/person).^{*}

equivalent to 3.8, 0.95, 0.21, 0.04, 0.03, and 0.009 mg, respectively, per 100 g fresh mushroom. Recommended dietary allowances (mg/day) of iron, zinc, and copper for average adult persons are 8/18, 11/8 (male/female), and 0.9, respectively [16], while provisional tolerable daily intake (PTDI) for Cd and Pb are 0.2 and 0.06, respectively [18]. Commission Regulation (EC) [33] has set maximum levels of Cd and Pb at 0.2 mg/kg wet weight and 0.3 mg/kg wet weight, respectively in oyster mushrooms like *Pleurotus ostreatus* [33]. For arsenic, the safe range value in toxicological guidance is 2–7 µg/kg body weight per day [17] allowing 0.12 mg of arsenic to be consumed daily by a person of 60 kg in weight. Considering the above-recommended values, an adult person can, therefore, safely consume 100 g of these experimental mushrooms daily without exceeding (Table 6) the permissible levels set by standard expert committee or commission for human consumption.

4. Conclusion

The above study indicates that the supplementation of rice straw with the weed water hyacinth supports a higher yield of oyster mushrooms and also reduces the production time of mushrooms. The small-scale mushroom farms or enterprises can maintain consistency in the supply of mushrooms throughout the year by cultivating different species of *Pleurotus* at their optimum temperatures in the same cropping room. The nutrient qualities of the mushrooms grown on common substrate rice straw are not adversely affected by the supplementation with water hyacinth. Besides, these oyster mushrooms will serve as good sources of protein as well as iron, zinc, and copper. The undesirable elements like lead, cadmium, or arsenic although translocated from the substrate to the mushroom, are not accumulating therein and their levels in the mushrooms fall in line with the recommendations by standard expert committee or commission. Regarding heavy metal contamination, the presence of some heavy metals in soil, air, water, and living objects are unavoidable contaminants and regular monitoring of these toxic elements in the mushrooms grown naturally or artificially is required to do vegetable safety. Utilization of water hyacinth as an alternate substrate for oyster mushroom cultivation can therefore contribute to reducing the cost of mushroom production as well as alleviating its adverse ecological impact. This will change the status of the aquatic

weed from prolific pest to the potential provider of protein-rich mushroom, whose controlled consumption daily will not pose any toxicological risk.

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