Middle East Journal of Agriculture Research
Volume: 12 | Issue: 01| Jan. – Mar.| 2023

EISSN: 2706-7955 ISSN: 2077-4605
DOI: 10.36632/mejar/2023.12.1.15
Journal homepage: www.curresweb.com
Pages: 178-196

Evaluating Untraditional Agro-Industrial Wastes in *Pleurotus ostreatus* Cultivation and its Spent Countervailing Composted Soil in Lettuce Plantation as an Added Value

Ahmed M. Eldin[1], Sohad F. S. Al-Sharnouby[1*], Amal I. Ramadan[2] and Khadiga I. M. ElGabry[1***]**

[1]Department of Soil Microbiology; Soils, Waters and Environmental Research Institute (SWERI), Agricultural Research Center (ARC), Giza, Egypt.
*Email: sohadmicro56@gmail.com, Orcid: https://orcid.org/0000-0003-4110-8029,
***Email: khadigagabry@yahoo.com, Orcid: https://orcid.org/0000-0002-6471-2512
[2]Central Laboratory for Environmental Quality Monitoring (CLEQM), National Water Research Center (NWRC), Cairo, Egypt.
**Email: amelibrahim2003@yahoo.com, Orcid: https://orcid.org/0000-0001-5359-6934,

Received: 18 Feb. 2023 **Accepted:** 25 Mar. 2023 **Published:** 30 Mar. 2023

ABSTRACT

The oyster mushroom *Pleurotus ostreatus* production in submerged culture (SMC) was conducted on variable agro-industrial wastes including rice straw (RS), sugarcane bagasse (SCB), orange peels (OP), olive mill pomace (OMP), moringa leaves (ML) and jojoba meal (JM), where RS, SCB, OP and OM offered *P. ostreatus* growth the highest dry weights and protein contents. Solid state culturing (SSC) for *P. ostreatus* was applied on RS, SCB, OP and OMP in combination and permutation. The best biological efficiencies (BE) and production rates (PR) for *P. ostreatus* were achieved in presence of OP mixed in combination with either RS, SCB or OM to be 86.6%, 173; 56.1%, 104 and 34.5%, 61 [BE%, PR], respectively. As the resulting spent mushroom substrates (SMS) were applied in pot experiment with soil for lettuce (*Lactuca sativa*) plantation, it was found to gradually countervail the role of compost and clay soil. The harvested *L. sativa* grown on SMS mixed in variable ratios of 25, 50 and 75% with composted clay soil increased harvested dry weight by 7, 15 and 3%, respectively, compared to composted soil alone. Correlation coefficients of chemical and physical analysis for both *P. ostreatus* and *L. sativa* against detected laccase, peroxidase and catalase activities were discussed.

Keywords: Pleurotus ostreatus, Lactuca sativa, SMS, catalase, laccase, peroxidase agroindustrial wastes

1. Introduction

Agroindustrial wastes, either as residues from agricultural field processes or as wastes resulting from food industries are considered added valuables rather than being an environmental problem. Their constituents of holocellulose, proteins, phenols and oils have been targeted in many production fields for human prosperity. Some of widely cultivated or newly introduced crops as sources for agroindustrial wastes in Egypt are shown in Table (1). Agroindustrial wastes availabilities were correlated to most recent data available for their source crop type, cultivation area and annual yield.

The structural content of wastes resulting from processing any crop and its amount could be predicted depending on their annual mass production and type of process applied during and after harvest. For instance, the amount of rice straw (RS) taken off the field depends mainly on the cutting height (Maguyon-Detras *et al.*, 2019). Also, moringa leaves (ML) analytical contents varied according to irrigation water quality and cultivation soil (Abdelaty *et al.*, 2022). The olive mill pomace (OMP)

Corresponding Author: Ahmed Mohy Eldin, Department of Soil Microbiology; Soils, Waters and Environmental Research Institute (SWERI), Agricultural Research Center (ARC), Giza, Egypt.
Email: ameaefe2006@yahoo.com, Orcid: https://orcid.org/0000-0003-4574-0777

resulting from olive oil extraction methods including traditional pressing, 3-phase and 2-phase systems differ in their structural analysis (Dermeche *et al.*, 2013).
On the other hand, the phenolic compounds as secondary metabolites in plants and their lignocellulosic wastes have free radical scavenging and antimicrobial effects. They vary in their function and structure including phenolic acids, flavonoids, lignins and tannins, which are widely discussed in many research studies, for instance: in RS (Elzaawely *et al.*, 2017), SCB (Zheng *et al.*, 2017), OMP (Chanioti *et al.*, 2021), CC (Hernández *et al.*, 2018), OP (Omoba *et al.*, 2015), ML (Hassan *et al.*, 2021) and JM (Wagdy *et al.*, 2011).

Table 1: Agroindustrial wastes availability in Egypt presented in descending order according to source crop cultivation area

Crop				Agroindustrial waste		
Name	**Area (ha)**	**Annual yield (MMT)**	**Year**	**Name**		**Estimated (MT)**
Sugarcane	128298 [(a)]	12.36 [(a)]	2021 [(a)]	**Sugarcane bagasse**	SCB	4176 [(b)]
Corn	$0.93x10^6$ [(c)]	7.44 [(c)]	2022-2023 [(c)]	**Corn cobs**	CC	-
Rice	$0.60x10^6$ [(c)]	3.60 [(c)]	2022-2023 [(c)]	**Rice straw**	RS	2.1 [(d)]
Olive	99102 [(a)]	0.98 [(a)]	2021 [(a)]	**Olive mill pomace**	OMP	50% [(e)]
Orange	17200 [(c)]	3.6 [(c)]	2022-2023 [(c)]	**Orange peel**	OP	30-40% [(f)]
Jojoba	-	229 ton [(g)]	2017 [(g)]	**Jojoba meal**	JM	-
Moringa	-	-	-	**Moringa leaves**	ML	-

MMT: million metric ton, MT: million ton,
(a) FAO statistical data (2022), (b) United nations database (2020), (c) USDA FAS (2023), (d) Central Agency for Public Mobilization and Statistics (CAPMAS), (e) Jerman and Mozetič (2012), (f) Meselhy *et al.* (2022), (g) Gabt (2020), (h) Barakat and Ghazal (2016)

Establishing consolidated bioprocesses using those agroindustrial wastes in mushroom production and even as soil amendments after being biologically modified are considered an important target worthy to study. Choosing mushroom cultivation on agroindustrial wastes was motivated by their capabilities and benefits. Mushrooms are the sporophore type of fungi that have fleshy fungus fruiting structure, some of which are edible and have worthy nutritional values. On the other hand, mushrooms as saprophytic basidiomycetes that belong to wood-degrading white-rot fungi are well known of their capabilities to grow on lignocellulosic wastes efficiently under controllable conditions, because of their extracellular enzymatic consortium that catalyze lignocellulosic degradation (Camassola *et al.*, 2013).

The oyster mushroom *Pleurotus ostreatus* is a species of white-rot fungi belongs to a subclass of lignin-degrading microorganisms that produce extracellular enzymes including cellulases, laccases (EC 1.10.3.2) and peroxidases (EC 1.11.1.7) (Palmieri *et al.*, 1997; Giardina *et al.*2000; Kumla *et al.*, 2020; Melanouri *et al.*, 2022). Laccases and peroxidases catalyze oxidation of several substances, particularly phenols and aromatic amines (d'Acunzo *et al.*, 2002). They both differ in their prosthetic groups, beside that laccases have lower oxidation potential than peroxidases (Kirk and Farrell, 1987; Hayashi and Yamazaki, 1979; Farhangrazi *et al.*, 1994). Mushroom growth in submerged and solid-state conditions on lignocellulosic wastes of different composition were widely studied among many researches (Elisashvili *et al.*, 2008; Téllez-Téllez *et al.*, 2008; An *et al.*, 2016). The growth of *P. ostreatus* begins with vegetative growth where its mycelia colonize the substrate followed by reproductive growth where its fruit body called basidiome is formed representing the mushroom itself (Díaz-Godínez *et al.*, 2017). In the submerged growth conditions or so-called submerged fermentation (SMF) the substrate is immersed in liquid state both sterilized and the application is progressing under more controlled aseptic conditions for studying and producing bioactive organic substances (Vamanu, 2012; Dudekulav *et al.*, 2020). On the other hand, the solid-state growth or so-called solid-state fermentation (SSF) is applied for mushroom fruiting production (Díaz-Godínez *et al.*, 2017). The enzyme production capacities vary under either growth conditions in which they favor SSF which have higher enzyme/biomass yield fraction (Viniegra-González *et al.*, 2003; Díaz-Godínez *et al.*, 2017).

The residue remaining from mushroom cultivation on agroindustrial wastes under solid state conditions and after being harvested was called spent mushroom waste (SMW), otherwise known as spent mushroom substrate (SMS). The remaining mushroom stipe and base in SMS was found to be

full of nutrients that shared in SMS quality (Cunha Zied *et al.*, 2020). SMS was directed by many research studies to compost production or to be used directly in soil mixtures as an added value. Composted SMS (SMC) was utilized as fertilizer and soil conditioner for horticulture applications (Umor *et al.*, 2021). On the other hand, the insist of using SMS as nutritional conditioner was reviewed in many studies (Zhang and Fadel, 2002; Medina *et al.*, 2012; Carmo *et al.*, 2021; Oliveira *et al.*, 2022). The use of spent mushroom substrate and its compost, specifically resulting from *P. ostreatus*, as soil conditioner and a competitive fertilizer in lettuce cultivation proved their reliability and efficiency in many previous studies (Zied *et al.*, 2021; Hernández *et al.*, 2021).

Soil enzymes are an important parameter in carbon sequestration and soil nutrient dynamics (Lemanowicz *et al.*, 2023). Soil enzymes activities are indicators for soil quality measuring soil microbial activity related to nutrient transformations (Ahamadou and Huang, 2012). Soil dehydrogenases (EC 1.1.1.) represent oxidoreductase enzymes that do not accumulate extracellularly in soil but occur inside microbial cells linked to their oxidoreduction processes and indicate overall soil microbial activity, as they do share in biological oxidation of soil organic matter (OM) upon which their activities are found proportional to microbial biomass in soil (Wolinska, and Stepniewsk, 2012). Peroxidase (EC 1.11.1.7) and catalase (EC 1.11.1.6) activities were used as indicators to quantify the stress conditions facing lettuce, specifically in their leaves (Aires *et al.*, 2021; Leitão *et al.*, 2021).

In the present research, the efficiency of using agroindustrial wastes in *P. ostreatus* growth under submerged and solid-state conditions followed by the use of resulting SMS in combination and permutation with composted soil in lettuce (*Lactuca sativa* L.) pot cultivation were studied.

2. Materials and Methods

2.1. Wastes

Sources from where the agro-industrial wastes were gathered included local farms for Rice straw (RS) and corn cobs (CC), juice shops for sugarcane bagasse (SCB) and orange peel (OP), while Olive milled pomace (OM), moringa leaves (ML) and jojoba meal (JM) were gathered from Agricultural Research Center (ARC) at Giza governorate – Egypt. All wastes were air dried, chopped or crushed to minimum size of 0.5 mm.

2.2. Mushroom and spawn preparation

Oyster mushroom (*Pleurotus ostreatus*) was generously offered by department of microbiology at SWERI - ARC – Egypt. The white-rot fungus was maintained on sterilized potato dextrose agar medium slants (PDA) containing: 200 g/l diced potatoes; 20 g/l glucose; 15 g/l agar, grown at 25°C for regular subculture. Inoculums were prepared on PDA plates from pre grown slants and used as source for mycelial agar disks (1 cm in diameter) for inoculation. Spawn was prepared as described by Atila (2016). The sorghum grains presoaked in water for 12 h were mixed with 10% wheat bran and 1% $CaCO_3$, on weight bases and were sterilized in glass bottles at 121°C for 30 min. Cooled bottles were inoculated with mycelial agar discs and incubated in the dark at 28 °C until completion of mycelial growth.

2.3. Submerged culturing (SMC)

Different wastes (20g) were distributed individually into 500ml jars, each containing 200 ml synthetic medium (g. L^{-1}): yeast extract (0.5), $(NH_4)_2SO_4$ (1.0) and tween 80 (1.0), pH was adjusted at 4.5, while the wide jars nozzles were firmly covered with thick cotton cloth sandwich pads and sterilized at 121°C for 15 min. The waste in each jar was inoculated with five mycelial agar discs and incubated at 28°C for 50±5 days until mushroom flush and harvest.

2.4. Solid State culturing (SSC)

Waste types on which *P. ostreatus* gave its highest yield were chosen as substrates for SSC. Dry wastes individually or mixed in combinations and permutations with other wastes in a weight ratio of 1:1, after which 10% (w/w) wheat bran and 1% (w/w) $CaCO_3$ were added to construct the substrate final form. Adequate water quantity was added to each substrate and mixed well so that they form a clump when squeezed without any excess water coming out. The moistened substrates of 1kg were filled into heat-resistant polypropylene bags and compressed well, after which a plastic neck was inserted around each bag mouth, plugged-in with cotton and sealed with a suitable rubber or aluminium

cap. After pasteurization, the bags were let to cool down to room temperature prior to inoculation with mushroom spawn under sterile conditions. Incubation was conducted in sanitized incubator at 28°C / humidity 70% in dark for 3-4 weeks, as primordia will be observed 1 week after complete colonization of the substrates. Mushroom fruiting bodies were harvested from two successive flushes (Yield) during production time (PT).

2.5. Plantation pot experiment:

Lettuce seedlings (*Lactuca sativa* L.) of 40 days old were brought from Horticulture Research Institute at ARC- Giza governorate. Lettuce transplants were selected for uniformity in size were transplanted in pots with size capacity of 10 kg soil (transplant /10 kg pot). The soil was mixed thoroughly with compost (35 g compost. Kg^{-1}soil). Pots were filled with soil compost mixture in 4 categories by volume, as shown in Table (2). The soil mixture introduced with SMS were mixed thoroughly as three combinations at instructed ratios before filling pots and SMS with/without compost as the 4^{th} and 5^{th} combinations. The pot experiment was conducted in pentaplicates (5 pots).

The NPK fertilization was followed after the recommendation of Agricultural Extension Office – Ministry of Agriculture – Egypt, at rates of 150: 45: 65 kg/ha as N: P_2O_5: K_2O, respectively, as mentioned by El-Mogy *et al.* (2020). NPK was applied as ammonium nitrate (33%N), calcium supper phosphate (15.5% P_2O_5) and C (48% K_2O) equivalent to 63, 8 and 23 Kg/fed of NPK, respectively. Calcium supper phosphate was added once to soil combinations in each pot before transplantation, while either of ammonium nitrate and potassium sulfate was added as half dose at a time after 15 and 30 days of plantation. After harvest, both lettuce and soil samples were collected for determination of yield parameters, chemical and biochemical properties. The other agricultural practices were done according to the recommended methods for lettuce crop (El-Ghinbihi, and Mahmoud, 2007).

Table 2: Pot design for planting *L. sativa* in combinations and permutations of soil, compost and spent mushroom substrate (SMS) mixtures.

Pot content	Combination	Soil % (V/V pot)	Compost (g/pot)	SMS % (V/V pot)
Soil mix (soil + compost)	C1	100	35	0
Soil mix + 25% SMS	C2	75	26.3	25
Soil mix + 50% SMS	C3	50	17.5	50
Soil mix + 75% SMS	C4	25	8.8	75
100% SMS (no soil mix)	C5	0	0	100
100% SMS + compost	C6	0	35	100

2.6. Physical and chemical analysis

Soil texture was identified by the amount of sand, silt, and clay, confirmed by soil saturation percentage (SP) as mentioned by Jones (2001). The soil pH values were measured according to Thomas (2018), soil electric conductivity (EC, dSm^{-1}) was determined according to Rhoades (2018), while the total dissolved solids TDS were estimated based on measured EC value, as TDS (ppm) = EC x 640 (Rusydi, 2018). Agro-industrial wastes, mushroom, lettuce harvests and soil were all dried in forced air oven at 70°C until stable weight to calculate their dry weights.

The concentrations of available elements in soil including calcium (Ca), magnesium (Mg), phosphorus (P) and sodium (Na) as major elements, copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) as micronutrients in soil sample digest (using a nitric acid/hydrogen peroxide ($HN0_3/H_20_2$) digestion mixture) were determined by inductively coupled plasma spectrometry (ICP) (Ultima 2 JY Plasma) done at Research and Studies Unit (component of analyzes and studies) at SWERI-ARC, as described by Kalra (1997). On the other hand, potassium was determined in the same digest by flame photometry according to the method of Chapman and Pratt (1962).

Organic matter (OM) and organic carbon (OC) were determined according to Nelson and Sommers (1996). Total nitrogen (TN) was determined using the micro-kejeldahl method and protein content was calculated based on determined nitrogen value (protein = 6.25 x N) as described by Miller and Horneck (1997). Holocellulose contents were determined using modified method described by Wise and Ratliff (1947). The samples were vacuum-dried at 40°C overnight and extracted with ethanol/toluene mixture (1:2 v/v) for 6h in Soxhlet, dried and weighed to calculate extractives.

Delignification of extracted dried sample (0.5 gram) was done by treating it with 0.2g NaClO in 30ml of 7.5% acetic acid solution at 80°C for 1h (4 times). The product was filtered, washed with distilled water several times, vacuum dried at 40°C for 24h and weighed as holocellulose. Fats were determined according to the methods described in AOAC (1990).

The total soluble solids (TSS) in lettuce leaves were measured by refractometer according to Magwaza and Opara (2015), as the results in "degrees Brix" (°Brix) were equivalent to percentages (%) (Dongare *et al.*, 2014).

Chlorophylls and carotenoids were extracted with acetone (100%) and determined according to Lichtenthaler and Buschmann (2001). Spectrophotometric absorption measurements (A) for chlorophyll a (C_a) and b (C_b) in acetone were done at 661.6nm and 644.8nm, respectively, while carotenoids (Carot) including carotene and xanthophyll were measured at 470nm. The following equations were applied (ug/ml):

$$C_a = 11.24\,A_{661.6} - 2.04\,A_{664.8}$$
$$C_b = 20.13\,A_{644.8} - 4.19\,A_{661.6}$$
$$Carot. = (1000\,A_{470} - 1.90\,C_a - 63.14\,C_b) \div 214$$

1.7. Enzyme activities

Fresh sample material of 0.5g was homogenized in 10 ml cold phosphate buffer (50 mM, pH 7). The homogenates were centrifuged at 4000 rpm at 20°C for 20 min. The supernatant was used as a raw extract for the enzymatic assay. Reagents used in the following assays were prepared in the same previously indicated buffer.

Laccase activity was assayed by determining the rate of ABTS oxidation (Childs, and Bardsley, 1975) following the update described by Palmieri *et al.* (1997). Oxidation of ABTS (1 ml, 0.03%) by the sample (1 ml) was monitored by increase in absorbance at 420 nm ($\varepsilon_{420\ nm}$ 36,000 M^{-1} cm^{-1}) at 30°C. One unit of laccase activity was defined as the amount of enzyme required to oxidize 1.0 µmol of ABTS per min.

Peroxidase activity was determined using methylene blue assay according to Magalhaes *et al.* (1996). The assay mixture contained 2.2 ml of the diluted supernatant, 0.1 ml of methylene blue (1.2 mM). The reaction was started by the addition of 0.1 ml of 2.7 mM H_2O_2. The conversion of the dye to Azure C was monitored by the measurement of the decrease in absorbance at 664 nm. One unit of peroxidase was defined as the amount of enzyme required to oxidize 1.0 µmol of methylene blue per min.

Catalase activity was assayed based on the breakdown of H_2O_2 detected in UV at 240nm, as mentioned by Beers and Sizer (1952). The method steps were done according to Pine *et al.* (1984), as 0.1 ml of sample was added to freshly prepared 1.4ml H_2O_2 (13.2M). The mixed solution was detected for loss in absorbance at 240nm. Units of catalase were calculated by using a molar absorbance index for H_20_2 of 43.6. One unit of catalase was defined as the amount of enzyme required to degrade 1.0 µmol of H_2O_2 per min.

Dehydrogenase activity (DeH-ase) was assayed using tri-phenyl tetra-zolium chloride (TTC) method according to Casida *et al.* (1964). Fresh soil sample of 2g added to 20ml capacity test tube followed by 2 ml TTC 1% in TRIS-HCl buffer (0.1M, pH 7) and incubated at 30°C/24 h. Extract with 10 ml methanol, shake and filter, after which absorbance was detected at 485nm. One unit of dehydrogenase was defined as the amount of enzyme required to hydrolyze of TTC to form 1.0 µmol of tri-phenyl formazan (TPF) per hour (µmol $g^{-1}h^{-1}$).

Phosphatase activity (P-ase) was measured using para nitro phenyl phosphate (PNPP) according to Tabatabai and Bremner (1969). As fresh soil of 1g was placed in 250ml Erlenmeyer flask, it was followed by adding 4ml of modified universal buffer (MUB) pH 6.5, 0.25ml toluene and 1ml PNPP. Incubation was processed at 30°C for 1h, after which 1ml $CaCl_2$ (0.5M) and 4ml NaOH (0.5M) were added and the resulting filtrate was measured for absorbance at 420nm. Phosphatase activity of one unit was defined as the amount of enzyme required to release 1µg of p-nitro phenol hydrolyze per hour.

1.8. Mushroom yield parameters

Mushroom was harvested from the first and second flushes in each trial, where its fresh weight (g) from the two flushes were gathered and represented the total yield (Y) from each trial. Biological

efficiency % (BE) and production rate (PR) were calculated afterwards as described by Moonmoon *et al*. (2011) according to the following equations:

$$\text{Biological efficiency \% BE} = \frac{\text{Yield (g)}}{\text{waste wt. (g)}} \times 100 ,$$

Waste wt.: 1000 g on dry basis
Yield: fresh weight in (g) of total mushroom fruiting bodies harvested from two flushes

$$\text{Production rate} \quad \text{PR} = \frac{\text{BE}}{\text{PT}} ,$$

PT: the total time in days required for production

1.9. Statistical analysis

All experimental trials were done in triplicates (n=3), except for the pot experiment which was done in pentaplicates (n=5). Data means, standard errors and correlation coefficients were analyzed and their graphs were constructed using Excel statistical program software (Microsoft office, 2007). Standard curve equations on which most of enzymatic assays were depending were constructed using Prism program version 5.03 for windows (GraphPad software, Inc.). Data analysis of variance (ANOVA) was done to determine their least significant differences (LSD) through one way completely randomized Ducan's Multiple Range test at significance level of 5% for one factor at a time (one way analysis) using CoStat 6.45 program (CoHort software 6.311).

3. Results and Discussion

3.1. Wastes analysis

Agroindustrial waste analysis presented in Figure (1) showed that the highest organic matter (90%) and fat (15%) contents were in OMP, holocellulose (61%) in RS and CC, protein in JM (23%) and most wide C/N ratio (82:1) was found in both SCB and RS.

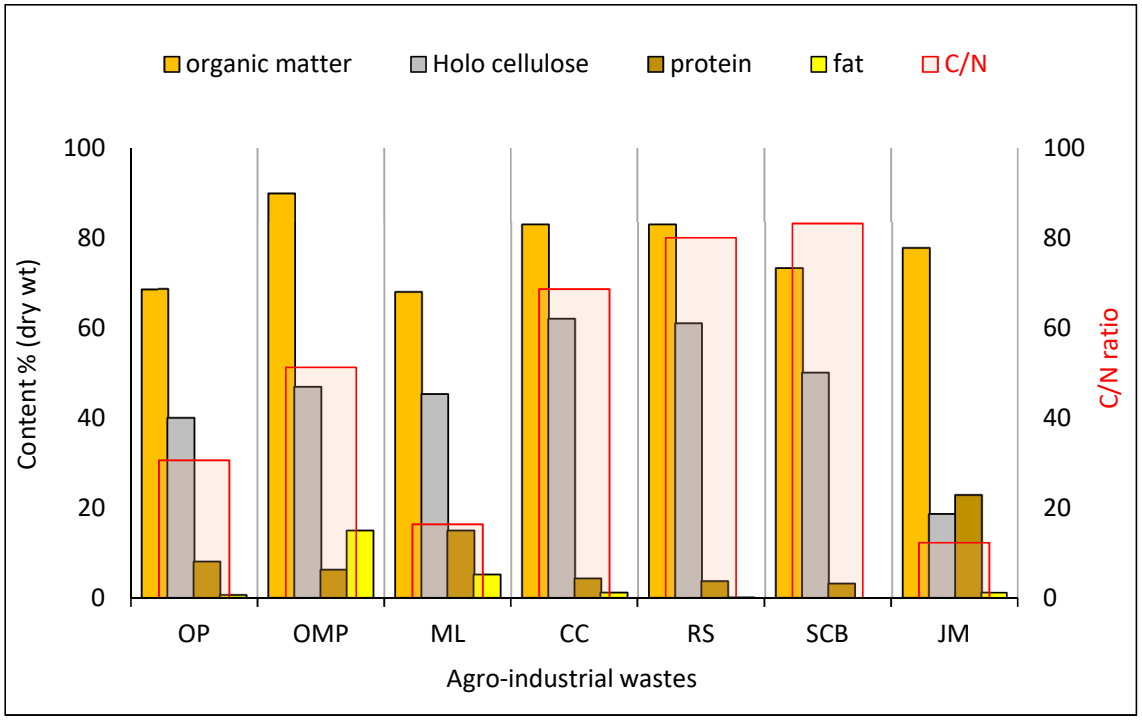

Fig. 1: Agroindustrial wastes major contents (%) analyzed on dry weight bases.

Compared to the presented waste analysis in our study, previous analytical studies reviewed on those wastes were close in their results. RS consisted of cellulose (32-47%) and hemicellulose (20-30%) (Karimi *et al.*, 2006). Also, SCB had high content in cellulose and hemicellulose to be 25-50 and 20-35, respectively (Mahmud and Anannya, 2021). CC structure of cellulose and hemicellulose were in range of 28-52 and 32-39%, respectively, while protein contents vary 3-11% (Medic *et al.*, 2012; Liu *et al.*, 2014; Shariff *et al.*, 2016). OMP contents of Protein 8-9%, while fat content varied widely from

5-30% (Ribeiro *et al.*, 2020; Nunes *et al.*, 2021; Podgornik *et al.*, 2022). OP comprised of holocellulose and oils (Pathak *et al.*, 2017; Czech *et al.*, 2021). JM was found to contain 10% oil (Mahmoud *et al.*, 2022) and 25-30% protein, (Abbassy *et al.*, 2007; Abdou, 2018). ML were found to be rich in proteins 23-30%, carbohydrates 53% and fat 4-9.5% (Abouel-Yazeed, 2019; Sultana, 2020).

3.2. Submerged culture SMC

Using SCB, OMP, OP and RS wastes in mushroom SMC achieved highest harvested dry weight results ranked a and ab based on statistical analysis (LSD 0.05 = 1.19) enforced with highest protein contents arranged by the same dwt descending order (LSD = 2.10), as presented in Figure (2a). The influence of C/N ratio was positive on both protein content (%) and mushroom yield (dwt) with mean correlation coefficient of +0.8, while on the contrary the fat content had negative impact on both by -0.8, as shown in Figure (3a).

Agro-industrial wastes used as substrates in mushroom cultivation are mostly low in nitrogen content materials, as the carbon/nitrogen (C/N) ratio was found to have influence on mushrooms growth, yield and protein content in their fruiting bodies (Hoa *et al.*, 2018; Grimm and Wosten, 2018). As for *P. ostreatus*, the optimum C/N of substrate used for highest yield was 45-66:1 (Kumla *et al.*, 2020).

On the other hand, either peroxidase and laccase activities presented in Figure (2b) had positive effect on shortening cultivation periods among the used wastes as shown in Figure (2a), clarified by negative correlation values of -0.6 and -0.4, respectively (Figure 3b). Compared to the present study, it was found that in many mushroom strains with higher level of peroxidases have shorter cultivation periods (Xu *et al.*, 2012).

Never the less, those agroindustrial wastes contained other constituents rather than holocellulose, proteins and fats that were found to affect microbial metabolism. For instance, lignins in RS, SCB and CC comprised about 5-24% (Karimi *et al.*, 2006), 14-23% (Mahmud and Anannya, 2021) and 10-19% (Medic *et al.*, 2012; Liu *et al.*, 2014; Shariff *et al.*, 2016). OMP contents of phenolic compounds included simple phenolic compounds, benzoic acids, cinnamic acid and secoiridoids (Miklavčič *et al.*, 2020), which were recorded to have many antibacterial activities (Nunes *et al.*, 2021). OP comprised lignin, pectin, chlorophyll pigments, β-carotene and other low-molecular weight compounds that some of them had been reported to have antibacterial effect (Pathak *et al.*, 2017; Czech *et al.*, 2021). Jojoba meal wastes (JM) was found to contain polyphenols, phytic and simmondsin glucoside toxin possessing antifungal activities (Abbassy *et al.*, 2007; Abdou, 2018).

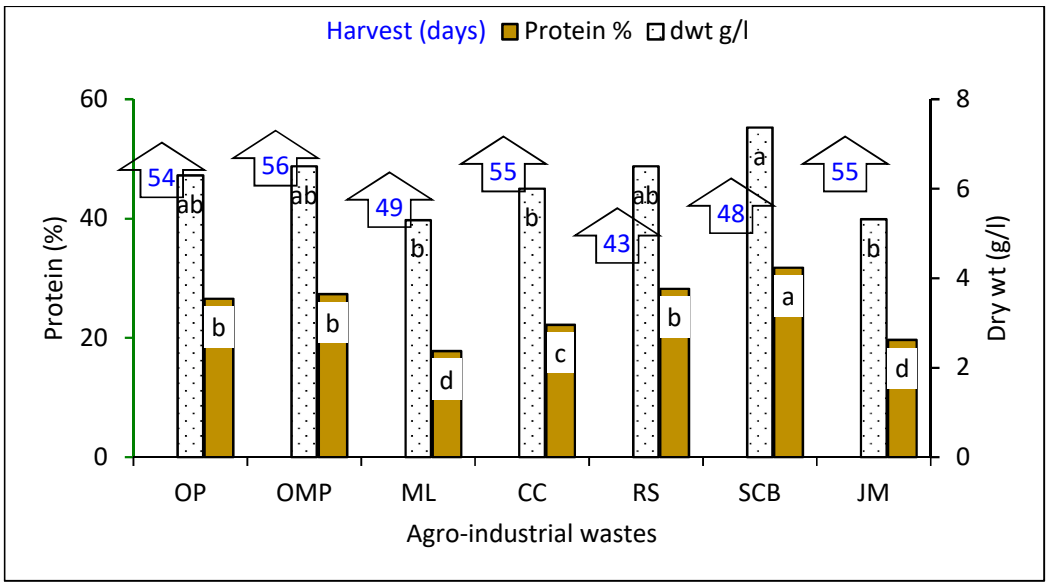

Fig. (2a): Harvest period (days), dry weight (dwt) and protein content of *P. ostreatus* grown on different agro-industrial wastes at harvest time, ranked statistically (LSD $_{0.05}$ = 2.10 for protein% and 1.19 for dwt).

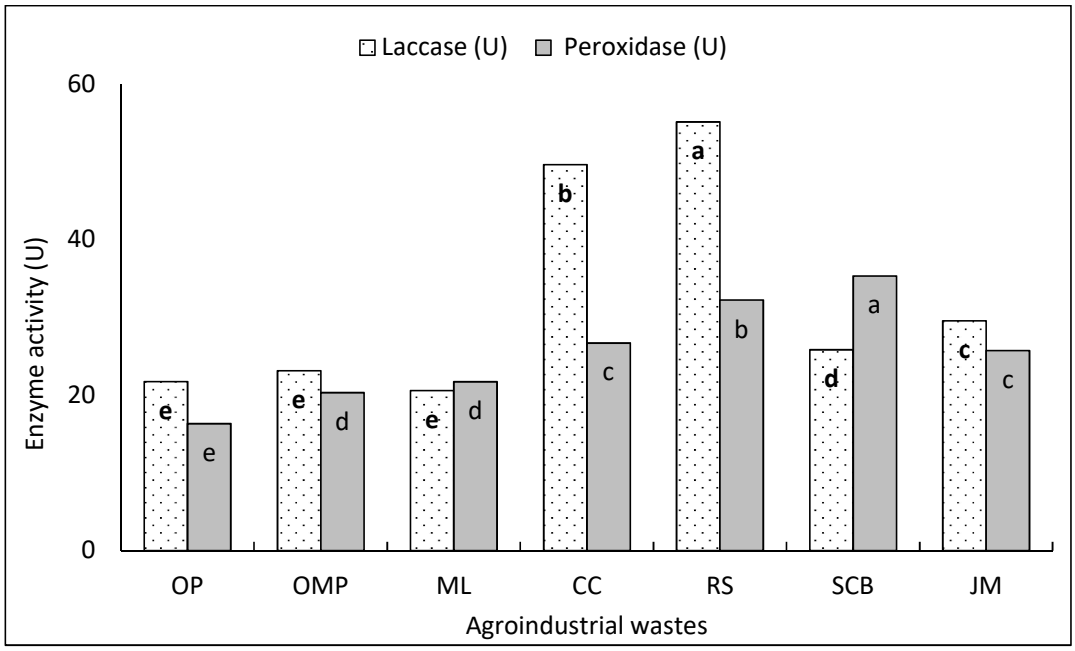

Fig. (2b): Laccase and peroxidase activities detected in culture medium broth of *P. ostreatus* grown on agroindustrial wastes at harvest time, ranked statistically (LSD $_{0.05}$ = 2.436 for laccase and 2.349 for peroxidase).

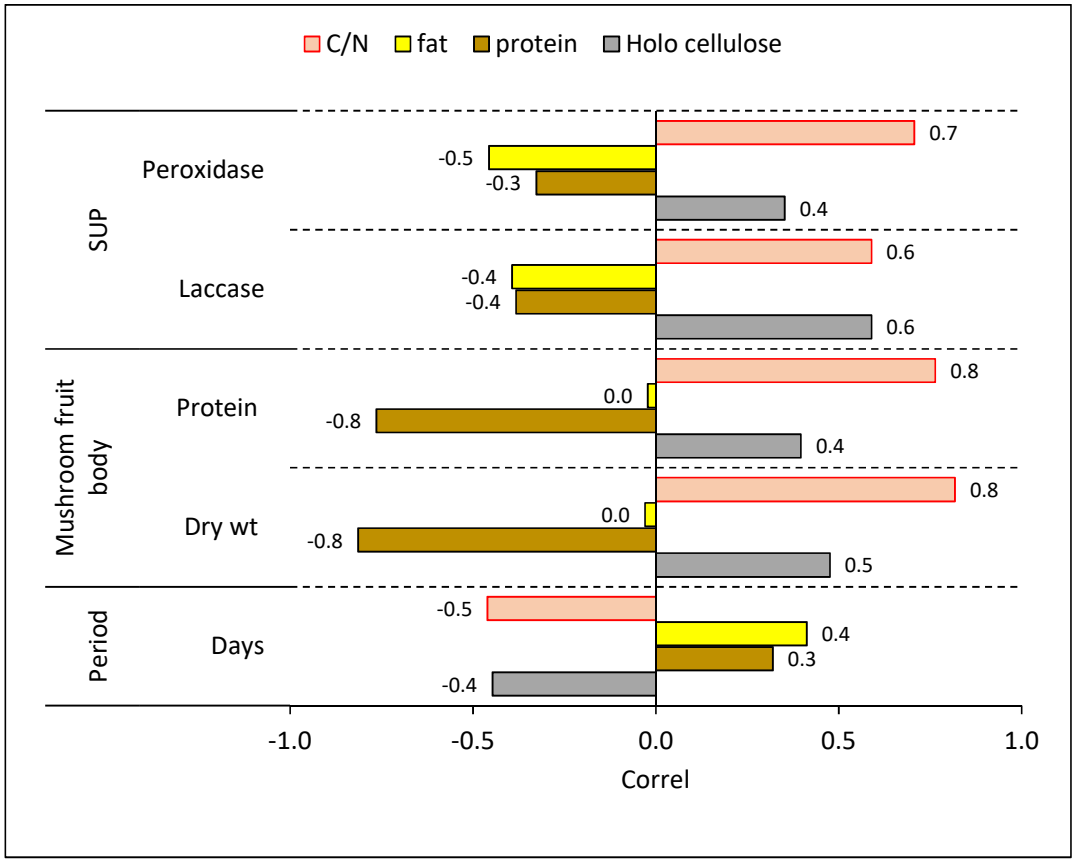

Fig. (3a): Correlation coefficient for agroindustrial wastes main contents used as substrate collectively against *P. ostreatus* laccase and peroxidase activities, protein content and dry weight.

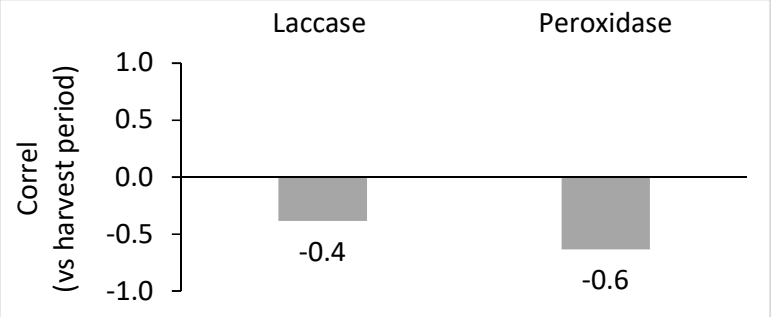

Fig. 3b: Correlation coefficient for *P. ostreatus* laccase and peroxidase activities vs harvest period (days).

2.1. Solid state culture

As presented in Table (3), the SCB, OMP, OP and RS wastes were used in combinations and permutations, of which *P. ostreatus* growth on RS+OP and SCB+OP achieved highest BE of 86.6% and 56.1%, respectively. Added to that, *P. ostreatus* growth on both waste mixtures achieved highest PR of 173 and 104, respectively, compared to other waste forms. The impacts of OP mixtures with RS or SCB were clarified by increasing BE and PR by >5 and >3 folds, compared to RS and SCB alone, respectively, calculated and presented in Table (3).

Not only with the presence of OP in waste mixtures achieved the best BE and PR, but the wider C/N ratios within those OP mixtures was a crucial factor positively correlated (+0.74 to +0.76) with better results as deduced in Figure (4). On the contrary, the fat contents had negative impact on BE and PR (-0.8).

Table 3: Biological efficiencies (BE%) and production rates (PR) for the yields of two flushes gathered from harvested *P. ostreatus* grown on agroindustrial wastes.

Waste mixtures	Content		Mushroom harvested							
	C/N	Fat%	BE% ± SE	Rank (LSD 8.6)	BE increase fold vs.		PR	PR increase fold vs.	
					RS+OP	SCB+OP		RS+OP	SCB+OP
RS	80.1	0.1	16.7 ± 2	e	5.2	3.4	33	5.3	3.2
RS+OMP	65.7	8	26.2 ± 1.5	cd	3.3	2.1	49	3.5	2.1
RS+OP	55.4	0.4	86.6 ± 6.2	a	1.0	0.6	173	1	0.6
SCB	83.2	0	10.8 ± 0.9	e	8.0	5.2	20	8.8	5.3
SCB+OMP	67.3	7.9	19.3 ± 0.9	de	4.5	2.9	34	5	3
SCB+OP	56.9	0.4	56.1 ± 2.4	b	1.5	1.0	104	1.7	1
OMP+OP	41	8.3	34.5 ± 2.1	c	2.5	1.6	61	2.9	1.7

BE from RS+OP and SCB+OP was considered profitable as they both exceeded 50%, according to Kumla *et al.* (2020). RS+OP achieved better BE compared to previous studies on *P. ostreatus* cultivation on agroindustrial wastes. For instance, combining straw from either rice or wheat with soya stalk recorded *P. ostreatus* BE of 82% and 78%, respectively (Liang *et al.*, 2019), while in other study, the cultivation using RS+SCB recorded lower BE of 50% (Ahmad *et al.*, 2020). Nevertheless, *P. ostreatus* grown on several wastes recorded biomass of 115 up to 454 mg/g dwt equivalent to BE of 12 to 50 % (Melanouri *et al.*, 2022). Worthy to notice that gathering either OP or OMP with wide C/N ratio waste such as RS or SCB enhanced BE values than that for either RS or SCB alone.

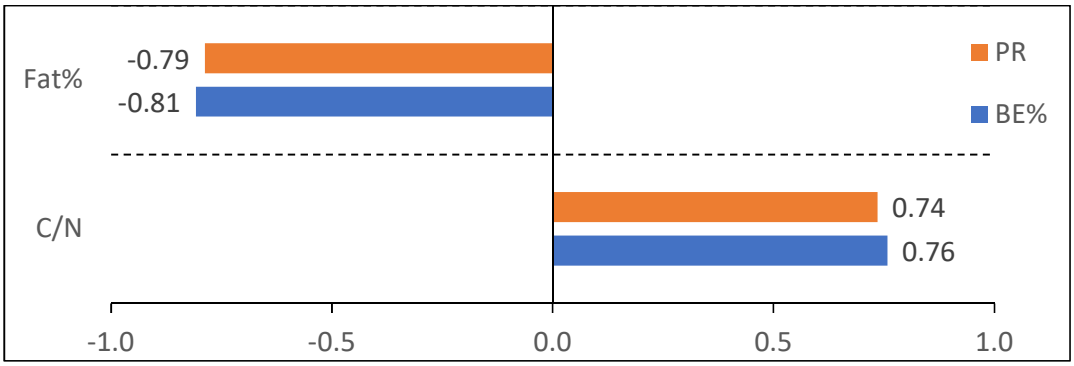

Fig. 4: Effect of C/N ratio and Fat content in (RS+OP, SCB+OP and OMP+OP) on their harvested mushroom BE% and PR submitted as correlation coefficient analysis.

2.1. Soil mixture analysis

2.1.1. Before harvest

Both SMS and compost were richer in OM with 136 and 70.8 fold than in soil, respectively, whereas the C/N ratio of SMS was found to be much bigger compared to that of soil and compost, as shown in table (4a). Added to that, SMS and compost constituent of P_2O_5 reformed about 17.6 and 76 folds, while K_2O reformed about 1.8 and 3.8 folds than those in soil, respectively.

According to data analysis in Table (4c), soil texture was found to be clay**.** Worthy to mention that saturation percentage (SP) that was found to be 47% ensured that soil sample had clay texture, as the SP lying in the range of 35-50% was found to characterize clay soils (Jones, 2001).

Table (4a): SMS, compost and soil analysis before plantation

Analyte	SMS		Comp		Soil	
O.M	81.82	%	42.50	%	0.60	%
C	47.46	%	24.65	%	0.40	%
N	1.04	%	1.80	%	0.2	%
C/N	46		14		16	
pH	5.7		7.3		8.48	
EC	1.93	$dS.m^{-1}$	2.3	$dS.m^{-1}$	1.66	$dS.m^{-1}$
P_2O_5	0.22	%	0.95	%	12.4	ppm
K_2O	0.42	%	0.87	%	230.0	ppm

Table (4b): Soil soluble ions and available nutrients before plantation

Soluble anions	$meq.l^{-1}$	Soluble Cations	$meq.l^{-1}$
$(CO_3)^{-1}$	ND	**$(K)^{+1}$**	0.32
$(HCO_3)^{-1}$	1.00	**$(Ca)^{+2}$**	5.50
$(Cl)^{-1}$	9.50	**$(Mg)^{+2}$**	3.50
$(SO_4)^{-2}$	6.06	**$(Na)^{+1}$**	7.25
Available Micronutrients	$mg.kg^{-1}$	**Available Macronutrients**	$mg.kg^{-1}$
Cu	0.040	**N**	215.0
Fe	1.040	**P**	12.4
Mn	0.386	**K**	230.0
Zn	0.152		

ND: not detected

Table (4c): Measurements identifying soil texture

Sand (%)	Silt (%)	Clay (%)	SP (%)
24.23	33.6	42.17	47

3.2.1. After harvest

Collectively among the six soil combinations used, both DeH-ase and P-ase residual activities measured in soil were found to be parallelly correlated to SMS share in soil recording +0.5 and +0.4, respectively, as presented in Table (5). Added to that, the TDS was much correlated to the SMS share in soil combinations (+0.6).

Consequently, enzymatic residual activities showed their strong parallel correlations with TDS in soil of (+0.76/0.78) collectively among the six soil combinations, that might be due to the important role of TDS in activities of the enzymes and/or their inducing effect on M.O colonizing soil combinations.

Table 5: Pot content combinations before transplantation and their analysis after harvest

	Pot content			Measured parameters in soil				
Pot combinations	**Compost (g/pot)**	**SMS % (v/v)**	**Clay soil % (v/v)**	**pH**	**EC**	**TDS**	**DeH-ase**	**P-ase**
C1	35	0	100	7.4	1.33	851	3.15	0.55
C2	26.3	25	75	7.4	1.47	941	2.83	3.12
C3	17.5	50	50	7.3	1.67	1069	1.81	2.09
C4	8.8	75	25	7.2	2.07	1325	2.92	2.05
C5	0	100	0	7.2	2.55	1632	7.19	4.64
C6	35	100	0	7.3	1.42	909	3.07	1.36
						TDS	0.76	0.78
Correlation coefficients					**Compost**	-0.96	-0.59	-0.77
					SMS	0.62	0.48	0.45
					Clay soil	-0.62	-0.48	-0.45

Correlation strength variations from strong colored as green (+) and red (-) to weak and no correlations towards yellow.

2.1. Lettuce yield and analysis at harvest

Lettuce harvested as presented in Figure (5) was labeled by its dimensions, while its analysis shown in Table (6), followed by further analysis revealing cross correlation coefficients between analyzed parameters as shown in Table (7).

Replacing composted clay soil with SMS by 25 and 50% (V/V) increased shoot length, leave no., shoot dry weight and protein content by 6.4, 2.1; 10.6, 19.8; 7, 15 and 1.8, 0%, respectively, calculated from results shown in Table (6). Within lettuce leaves harvested from 25 and 50% SMS combinations, both total chlorophyll (TC) and carotenoid (Carot) contents increased by 217, 105 and 225, 117% than 100% composted clay soil, respectively. On the other hand, catalase activities decreased by 81.7 and 33.4%, while peroxidase activity increased by 95.3 and 4.7%, respectively.

High positive correlations (+0.8 to +0.9) gathered leaves dry weight with shoot height, shoot to root length ratio, head diameter, leaves protein content and considerable positive correlation (+0.4 to +0.6) with leaves no., total chlorophylls and total carotenoids, which are considered good parameters for economic evaluation. On the contrary, the leaves dry weight was negatively correlated (-0.8 to -0.9)

Table 6: Lettuce *Lettuce L. sativa* analysis after harvest

POT combinations	S	R	S/R	L	H	L/H	DW	TSS	P	C_a	C_b	C_a/C_b	TC	Carot	TC /Carot	Cat	POD
C1	23.50	7.00	3.36	21.70	1.60	13.56	176	4.87	20.7	130	25.2	5.2	155	15.5	10.01	7.0	0.086
C2	25.00	7.00	3.57	24.00	2.00	12.00	188	4.63	21.1	369	122.0	3.0	491	50.4	9.73	1.3	0.168
C3	24.00	7.50	3.20	26.00	1.70	15.29	202	5.21	20.7	245	72.5	3.4	317	43.0	7.37	4.7	0.090
C4	20.50	9.00	2.28	15.00	1.44	10.42	181	4.36	22.4	97	15.0	6.5	112	22.7	4.94	11.1	0.059
C5	17.50	10.50	1.67	15.00	0.80	18.75	106	3.98	18.9	176	50.6	3.5	227	23.9	9.47	4.2	0.289
C6	17.50	14.00	1.25	19.70	1.00	19.70	104	2.95	18.9	103	10.1	10.2	113	19.0	5.94	10.0	0.072

Shoot height (S), Root depth (R), Leaves no (L), Head diameter (H), Dry Weight (DW), total soluble solids (TSS), Protein (P), Chlorophyll Ca (C_a), Chlorophyll (C_b), Total chlorophyll (TC), Carotenoids (Carot), Catalase (Cat)

Table 7: Correlation coefficients characterizing interactions between analyzed parameters of harvested lettuce *L. sativa* collectively among the six soil combinations used in pots.

	R	S/R	L	H	L/H	DW	TSS	Prot	C_a	C_b	Ca/C_b	TC	Carot	TC /Carot	Cat	POD
S	-0.9	1.0	0.8	1.0	-0.7	0.9	0.8	0.6	0.7	0.6	-0.6	0.6	0.6	0.4	-0.5	-0.3
R		-0.9	-0.5	-0.8	0.7	-0.9	-1.0	-0.7	-0.5	-0.6	0.8	-0.5	-0.5	-0.5	0.5	0.0
S/R			0.7	0.9	-0.7	0.9	0.9	0.6	0.6	0.6	-0.7	0.6	0.6	0.5	-0.5	-0.2
L				0.7	-0.1	0.6	0.5	0.1	0.6	0.6	-0.3	0.6	0.6	0.3	-0.5	-0.3
H					-0.8	0.9	0.7	0.7	0.6	0.6	-0.5	0.6	0.7	0.2	-0.4	-0.4
L/H						-0.8	-0.6	-1.0	-0.2	-0.3	0.3	-0.2	-0.3	0.0	0.0	0.4
DW							0.9	0.8	0.4	0.4	-0.5	0.4	0.6	0.1	-0.2	-0.4
TSS								0.6	0.5	0.5	-0.8	0.5	0.5	0.4	-0.5	-0.1
Prot									0.1	0.1	-0.2	0.1	0.3	-0.3	0.1	-0.5
C_a										1.0	-0.7	1.0	0.9	0.5	-0.9	0.4
C_b											-0.8	1.0	0.9	0.5	-0.9	0.4
Ca/C_b												-0.7	-0.6	0.5	0.8	-0.5
TC													0.9	0.5	-0.9	0.4
Carot														0.2	-0.7	0.2
TC /Carot															-0.8	0.6
Cat																-0.6

Shoot height (S), Root depth (R), Leaves no (L), Head diameter (H), Dry Weight (DW), total soluble solids (TSS), Protein (P), Chlorophyll Ca (C_a), Chlorophyll (C_b), Total chlorophyll (TC), Carotenoids (Carot), Catalase (Cat). Correlation strength variations from strong colored as green (+) and red (-) to weak and no correlations towards yellow.

to root length and leaves no to head diameter ratio, with considerable negative correlation (-0.4 to -0.5) with chlorophyll C_a to C_b ratio and peroxidase activity in leaves.

Catalase activity was negatively correlated to total chlorophyll and carotenoids. On the other hand, leaf number and shoot height were negatively correlated to catalase but were positively correlated to total chlorophyll and carotenoids, as same results were deduced by Zhao *et al.* (2022). Catalase activity in leaves of lettuce *L. sativa* was found to share in scavenging the reactive oxygen species resulting from oxidative stress. In plants, catalase scavenges H_2O_2 generated mainly during mitochondrial photorespiratory oxidation and electron transport, beside β-oxidation of the fatty acids. (Leitão *et al.*, 2021)

Most obvious that SMS pushed lettuce to increase its carotenoid contents which was considered as nonenzymatic antioxidants (Sharma *et al.*, 2012), that was more correlated to shoot length, leave no, dry weight and total chlorophyll, while on the contrary catalase activity decreased. On the same trend, chlorophyll C_a to C_b ratio (C_a/C_b) decreased with increasing carotenoid level while C_a/C_b increased with catalase activity. These results indicated that the plant leaves tended to convert more chlorophyll C_a to C_b (ie: decrease in C_a/C_b) parallel to catalytic activity facing any possible stress, while in reversible correlation with carotenoid level that seemed to be dependable on chlorophyll C_a form than C_b. The chlorophyll C_a to C_b ratio was found to decrease, as chlorophyll C_a tended to be replaced by chlorophyll C_b (Sarijeva *et al.*, 2007), with many forms of stress factors including decreasing N availability, high light conditions or increasing EC above 2 dSm^{-1} among most lettuce cultivars (Kitajima and Hogan, 2003; Adhikari *et al.*, 2019).

Worthy to mention that increasing SMS to 75% in pot increased EC above 2 dSm^{-1} at which stress began to affect lettuce growth and final yield, as mentioned before by Adhikari *et al.* (2019), which was reflected as drop in dry weight, total chlorophyll, carotenoids and peroxidase activity, while catalase activity increased.

microbial origin, reflecting the whole residual microbial activities at harvest time. Microbial DeH-ase and P-ase had their impact on lettuce growth extended during cultivation period that were translated into lettuce yield and analysis at harvest time. Their correlations revealed their positive impact on L/D, TC/Carot and POD in lettuce as shown in Table (8).

Table 8: Correlations between Lettuce analytical data vs soil analysis after harvest.

Lettuce analysis at harvest	Soil analysis at harvest			
	pH	**TDS**	**DeH-ase**	**P-ase**
S/R	0.69	-0.46	-0.51	-0.22
L/D	-0.22	0.16	0.48	0.21
Dry Weight	0.40	-0.36	-0.70	-0.30
TSS	0.33	-0.10	-0.35	-0.07
protein	0.07	-0.12	-0.56	-0.27
C_a/C_b	-0.15	-0.28	-0.18	-0.53
TC	0.47	-0.14	-0.14	0.43
TC/Carot	0.55	-0.08	0.36	0.27
Cat	-0.42	-0.01	-0.18	-0.55
POD	-0.24	0.65	0.86	0.89

In lettuce: Shoot height/Root height (S/R), Leaves no/Head diameter (L/D), Total soluble solids (TSS), Chlorophyll Ca/Chlorophyll Cb (C_a/C_b), Total chlorophyll (TC), Total chlorophyll/Carotenoids (TC/Carot), Catalase (Cat), Peroxidase (POD).
In soil: pH value, Total dissolved solids (TDS), Dehydrogenase (DeH-ase), Phosphatase (P-ase).
Correlation strength variations from strong colored as green (+) and red (-) to weak and no correlations towards yellow.

Figure (5): *L. sativa* grown on soil, compost and SMS mixtures at harvest time. Yellow ruler bars (cm) showing lettuce part dimensions.

3.3. Conclusion

The orange peel increased *P. ostreatus* production only when it participated with other agro-industrial wastes with wide C/N ratio, in spite of containing antimicrobial contents, as both production rate and transformation of RS to mushroom yield (BE) increased by >5 folds compared to usual rice straw alone. On the same trend, orange peel leveled up production rate and transformation of SCB by >3 folds. Those achievements of bigger yield in shorter time improvement are considered of high economic outcome.

Never the less, the harvested *L. sativa* grown on SMS mixed with composted clay soil in variable ratios of 25 and 50% (V/V) increased harvested dry weight by 7 and 15%, respectively, with higher protein, total chlorophyll and carotenoid contents almost doubled compared to composted soil alone, adding undeniable economic value for using SMS soil mixture in lettuce cultivation.

References

Abbassy, MA., SAM. Abdelgaleil, ASH. Belal and MAAA. Rasoul, 2007. Insecticidal, antifeedant and antifungal activities of two glucosides isolated from the seeds of *Simmondsia chinensis*. Ind. Crops Prod., 26(3):345–50

Abdelaty, H., A. Hosni, A. Abdelhamid and A. Abdalla, 2022. Effect of irrigation water quantity and salinity level on growth and internal chemical contents of Moringa plants. Egypt. J. Chem., 65(12): 79–85. https://doi.org/10.21608/ejchem.2022.144021.6283

Abdou, A., 2018. Nutritional evaluation of treated jojoba meal by *Aspergillus oryzae* as sheep feed. Egypt. J. Nutr. Feeds, 21(1): 35–51. https://doi.org/10.21608/ejnf.2018.75393

Abouel-Yazeed, A., 2019. Usage of moringa leaves as a component in some foodstuff. J. of Food and Dairy Sci., 10(10): 365–371. https://doi.org/10.21608/jfds.2019.59706

Adhikari, N. D., I. Simko and B. Mou, 2019. Phenomic and physiological analysis of salinity effects on lettuce. Sensors, 19(21): 4814. https://doi.org/10.3390/s19214814

Ahamadou, B. and Q. Huang, 2012. Impacts of agricultural management practices on soil quality. Progr. Soil. Sci., 429–480. https://doi.org/10.1007/978-94-007-4177-5_15

Ahmad Zakil, F., K. H. Muhammad Hassan, M. S. Mohd Sueb and R. Isha, 2020. Growth and yield of *Pleurotus ostreatus* using sugarcane bagasse as an alternative substrate in Malaysia. IOP Conference Series: Mater. Sci. Eng., 736(2): 022021. https://doi.org/10.1088/1757-899x/736/2/022021

Aires, E. S., C. A. Aragão, B. F. Dantas, J. D. Rodrigues and E. O. Ono, 2021. Light intensity modulates the accumulation of carbohydrates, antioxidant enzymes and production of iceberg lettuce under tropical conditions. Horticulturae, 7(12): 553. https://doi.org/10.3390/horticulturae7120553

An, Q., X.-J. Wu, M.-L. Han, B.-K. Cui, S.-H. He, Y.-C. Dai and J. Si, 2016. Sequential solid-state and submerged cultivation of the white rot fungus *Pleurotus ostreatus* on biomass and the activity of lignocellulolytic enzymes. BioResources, 11(4). https://doi.org/10.15376/biores.11.4.8791-8805

AOAC, 1990 In: Official Methods of Analysis of The Association of Official Analytical Chemists, 15th ed. (ed. by W. Horwitz), Association of Official Analytical Chemists, Arlington, VA, USA,1298pp.

Atila, F., 2016. Effect of different substrate disinfection methods on the production of *Pleurotus ostreatus*. J. Agric. Sci., 4(4): 52. https://doi.org/10.5296/jas.v4i4.10051

Barakat, H. and G.A. Ghazal, 2016. Physicochemical properties of *Moringa oleifera* seeds and their edible oil cultivated at different regions in Egypt. Food Sci. Nutr., 7: 472-484. http://dx.doi.org/10.4236/fns.2016.76049

Beers, R. F., and I. W. Sizer, 1952. A spectrophotometric method for measuring the breakdown of hydrogen peroxide by catalase. J. Biol. Chem., 195(1): 133–140. https://doi.org/10.1016/s0021-9258(19)50881-x

Camassola, M., L. O. da Rosa, R. Calloni, T. A. Gaio and A. J. P. Dillon, 2013. Secretion of laccase and manganese peroxidase by *Pleurotus* strains cultivate in solid-state using Pinus spp. sawdust. Braz. J. Microbiol., 44(1): 207–213. https://doi.org/10.1590/s1517-83822013005000006

Carmo, C. O. D., M. D. S. Rodrigues, F. D. Silva, T. G. M. Irineu, and A. C. F. Soares, 2021. Spent mushroom substrate of *Pleurotus ostreatus* kummer increases basil biomass and essential oil yield. Rev. Caatinga, 34(3): 548–558. https://doi.org/10.1590/1983-21252021v34n306rc

Casida, L., D. Klein and T. Santoro, 1964. Soil Dehydrogenase Activity. Soil Sci., 98: 371-376. https://doi.org/10.1097/00010694-196412000-00004

Central Agency for Public Mobilization and Statistics (CAPMAS), 2019. https://www.capmas.gov.eg/Admin/News/PressRelease/202012171183_666%20e.pdf

Chanioti, S., M. Katsouli and C. Tzia, 2021. Novel processes for the extraction of phenolic compounds from olive pomace and their protection by encapsulation. Mol., 26(6), 1781. https://doi.org/10.3390/molecules26061781

Chapman, H.D. and P.F. Pratt, 1962. Methods of analysis for soils, plants and water. Soil Sci., 93(1):68. doi: 10.1097/00010694-196201000-00015

Childs, R. E., and W. G. Bardsley, 1975. The steady-state kinetics of peroxidase with 2,2′-azino-di-(3-ethyl-benzthiazoline-6-sulphonic acid) as chromogen. Biochem. J., 145(1): 93–103. https://doi.org/10.1042/bj1450093

Costat Software, 1985. User's Manual-Version 3, CoHort. Tusson. Arizona, U. S. A.

Cunha Zied, D., J. E. Sánchez, R. Noble and A. Pardo-Giménez, 2020. Use of spent mushroom substrate in new mushroom crops to promote the transition towards a circular economy. Agron., 10(9), 1239. https://doi.org/10.3390/agronomy10091239

Czech, A., A. Malik, B. Sosnowska and P. Domaradzki, 2021. Bioactive substances, heavy metals, and antioxidant activity in whole fruit, peel, and pulp of citrus fruits. Int. J. Food Sci., 2021: 1–14. https://doi.org/10.1155/2021/6662259

d'Acunzo, F., C. Galli and B. Masci, 2002. Oxidation of phenols by laccase and laccase-mediator systems. Eur. J. Biochem., 269(21): 5330–5335. Portico. https://doi.org/10.1046/j.1432-1033.2002.03256.x

Dermeche, S., M. Nadour, C. Larroche, F. Moulti-Mati and P. Michaud, 2013. Olive mill wastes: Biochemical characterizations and valorization strategies. Process Biochem., 48(10): 1532–1552. https://doi.org/10.1016/j.procbio.2013.07.010

Díaz-Godínez, G., M. Téllez-Téllez, C. Sánchez, and R. Díaz, 2017. Characterization of the solid-state and liquid fermentation for the production of laccases of *Pleurotus ostreatus*. fermentation processes. https://doi.org/10.5772/64239

Dongare, M. L., P. B. Buchade, M. N. Awatade and A. D. Shaligram, 2014. Mathematical modeling and simulation of refractive index-based Brix measurement system. Optik, 125(3), 946–949. https://doi.org/10.1016/j.ijleo.2013.09.002

El-Ghinbihi, F. and W. Mahmoud, 2007. Physiological studies on the effect of some beneficial microorganisms on lettuce plants polluted by lead. J. Plant Prot. & Pathol., 32(5): 3823–3848. https://doi.org/10.21608/jppp.2007.21953

Elisashvili, V., M. Penninckx, E. Kachlishvili, N. Tsiklauri, E. Metreveli, T. Kharziani and G. Kvesitadze, 2008. *Lentinus edodes* and *Pleurotus* species lignocellulolytic enzymes activity in submerged and solid-state fermentation of lignocellulosic wastes of different composition. Bioresour. Technol., 99(3): 457–462. https://doi.org/10.1016/j.biortech.2007.01.011

El-Mogy, M. M., S. M. Abdelaziz, A. W. M. Mahmoud, T. R. Elsayed, N. H. Abdel-Kader and M. I. A. Mohamed, 2020. Comparative effects of different organic and inorganic fertilisers on soil fertility, plant growth, soil microbial community, and storage ability of lettuce. Agriculture (Pol'nohospodárstvo), 66(3): 87–107. https://doi.org/10.2478/agri-2020-0009

Elzaawely, A. A., H. F. Maswada, M. E. A. El-Sayed, and M. E. Ahmed, 2017. phenolic compounds and antioxidant activity of rice straw extract. Int. Lett. Nat. Sci., 64: 1–9. https://doi.org/10.18052/www.scipress.com/ilns.64.1

FAOSTAT, Food and agriculture data. 2022. https://www.fao.org/faostat/en/?fbclid=IwAR1wIWI09NDACqUefj-mNR2tJrt0ZrRoYYxC3fAVsKNDuGWpwSrcHnzbgs8#data/QCL

Farhangrazi, Z. S., B. R. Copeland, T. Nakayama, T. Amach, I. Yamazaki, and L. S. Powers. 1994. Oxidation-reduction properties of compounds I and II of *Arthromyces ramosus* peroxidase. Biochemistry, 33:5647–5652.

Gabt, R., 2020. A study of investment efficiency for jojoba crop production in red sea governoreat. J. Product. & Dev., 25(1): 61–77. https://doi.org/10.21608/jpd.2020.81015

Giardina, P., Palmieri, G., Fontanella, B., Rivieccio, V., and Sannia, G. (2000). Manganese Peroxidase Isoenzymes Produced by *Pleurotus ostreatus* Grown on Wood Sawdust. Arch. Biochem. Biophys., 376(1), 171–179. https://doi.org/10.1006/abbi.1999.1691

Grimm, D., and H. A. B. Wösten, 2018. Mushroom cultivation in the circular economy. Appl. Microbiol. Biotechnol., 102(18): 7795–7803. https://doi.org/10.1007/s00253-018-9226-8

Hassan, M. A., T. Xu, Y. Tian, Y. Zhong, F. A. Z. Ali, X. Yang and B. Lu, 2021. Health benefits and phenolic compounds of Moringa oleifera leaves: A comprehensive review. Phytomed., 93: 153771. https://doi.org/10.1016/j.phymed.2021.153771

Hayashi, Y., and I. Yamazaki. 1979. The oxidation-reduction potentials of compound I/compound II and compound II/ferric couples of horseradish peroxidases A2 and C. J. Biol. Chem. 254:9101–9106

Hernández, D., M. Ros, F. Carmona, J. Saez-Tovar, and J. Pascual, 2021. Composting spent mushroom substrate from *Agaricus bisporus* and *Pleurotus ostreatus* production as a growing media component for baby leaf lettuce cultivation under pythium irregulare biotic stress. Horticulturae, 7(2): 13. https://doi.org/10.3390/horticulturae7020013

Hernández, M., J. Ventura, C. Castro, V. Boone, R. Rojas, J. Ascacio-Valdés, and G. Martínez-Ávila, 2018. UPLC-ESI-QTOF-MS2-based identification and antioxidant activity assessment of phenolic compounds from red corn cob (*Zea mays* L.). Molecules, 23(6): 1425. https://doi.org/10.3390/molecules23061425

Hoa, H. T., C.-L. Wang, and C.-H. Wang, 2015. The effects of different substrates on the growth, yield, and nutritional composition of two oyster mushrooms (*Pleurotus ostreatus* and *Pleurotus cystidiosus*). Mycobiology, 43(4): 423–434. https://doi.org/10.5941/myco.2015.43.4.423

Jerman Klen, T. and B. Mozetič Vodopivec, 2012. The fate of olive fruit phenols during commercial olive oil processing: Traditional press versus continuous two- and three-phase centrifuge. LWT, 49(2): 267–274. https://doi.org/10.1016/j.lwt.2012.03.029

Jones, Jr. 2001. Laboratory Guide for Conducting Soil Tests and Plant Analysis. https://doi.org/10.1201/9781420025293

Kalra, Y. (Ed.). 1997. Handbook of Reference Methods for Plant Analysis. https://doi.org/10.1201/9781420049398

Karimi, K., G. Emtiazi and M. J. Taherzadeh, 2006. Production of ethanol and mycelial biomass from rice straw hemicellulose hydrolyzate by *Mucor indicus*. Process Biochem., 41(3): 653–658. https://doi.org/10.1016/j.procbio.2005.08.014

Kirk, T. K. and R. L. Farrell, 1987. Enzymatic "combustion": the microbial degradation of lignin. Annu. Rev. Microbiol., 41: 465–505. https://doi.org/10.1146/annurev.mi.41.100187.002341

Kitajima, K. and K. P. Hogan, 2003. Increases of chlorophyll Ca/b ratios during acclimation of tropical woody seedlings to nitrogen limitation and high light. Plant Cell Environ, 26(6): 857–865. Portico. https://doi.org/10.1046/j.1365-3040.2003.01017.x

Kumla, J., N. Suwannarach, K. Sujarit, W. Penkhrue, P. Kakumyan, K. Jatuwong, S. Vadthanarat, and S. Lumyong, 2020. Cultivation of mushrooms and their lignocellulolytic enzyme production through the utilization of agro-industrial waste. Molecules, 25(12): 2811. https://doi.org/10.3390/molecules25122811

Leitão, I., M. P. Mourato, L. Carvalho, M. C. Oliveira, M. M. Marques and L. L. Martins, 2021. Antioxidative response of lettuce (*Lactuca sativa*) to carbamazepine-induced stress. Environ. Sci. Pollut. Res., 28(33): 45920–45932. https://doi.org/10.1007/s11356-021-13979-3

Lemanowicz, J., A. Bartkowiak, A. Zielińska, I. Jaskulska, M. Rydlewska, K. Klunek and M. Polkowska, 2023. The effect of enzyme activity on carbon sequestration and the cycle of available macro- (p, k, mg) and microelements (zn, cu) in phaeozems. Agriculture, 13(1): 172. https://doi.org/10.3390/agriculture13010172

Liang, C.-H., C.-Y. Wu, P.-L. Lu, Y.-C. Kuo and Z.-C. Liang, 2019. Biological efficiency and nutritional value of the culinary-medicinal mushroom Auricularia cultivated on a sawdust basal substrate supplement with different proportions of grass plants. Saudi J. Biol. Sci., 26(2): 263–269. https://doi.org/10.1016/j.sjbs.2016.10.017

Lichtenthaler, H. K. and C. Buschmann, 2001. Extraction of photosynthetic tissues: chlorophylls and carotenoids. Curr. protoc. food anal. chem., 1(1): F4.2.1-F4.2.6. Portico. https://doi.org/10.1002/0471142913.faf0402s01

Liu, X., Y. Zhang, Z. Li, R. Feng and Y. Zhang, 2014. Characterization of corncob-derived biochar and pyrolysis kinetics in comparison with corn stalk and sawdust. Bioresour. Technol., 170: 76–82. https://doi.org/10.1016/j.biortech.2014.07.077

Magalhaes, D.B., M.E.A. de Carvalho, E. Bon, J.S.A. Neto and S.H. Kling, 1996. Colorimetric assay for lignin peroxidase activity determination using methylene blue as substrate, Biotechnol. Tech. 10:273–276, https://doi.org/10.1007/BF00184028

Maguyon-Detras, M.C., M.V.P. Migo, N. Van Hung and M. Gummert, 2020. Thermochemical conversion of rice straw. In: Gummert, M., N. Hung, P. Chivenge, B. Douthwaite, (eds) Sustainable rice straw management. 43–64. Springer, Cham. https://doi.org/10.1007/978-3-030-32373-8_4

Magwaza LS and UL. Opara, 2015. Analytical methods for determination of sugars and sweetness of horticultural products: A review. Sci. Hort. 184:179-192. https://doi.org/10.1016/j.scienta.2015.01.001

Mahmoud G.A.-E., R. Abdel-Basset, M.A. Abdel-Sater and A.G. Sayed, 2022. Utilization of coconut and jojoba wastes for lipases production by *Aspergillus niger* and applied it for biodiesel production. Glob. Nest J., 24(3): 495-504. https://doi.org/10.30955/gnj.004287

Mahmud, Md. A. and F. R. Anannya, 2021. Sugarcane bagasse - A source of cellulosic fiber for diverse applications. Heliyon, 7(8): e07771. https://doi.org/10.1016/j.heliyon.2021.e07771

Medic, D., M. Darr, A. Shah, and S. Rahn, (2012). The effects of particle size, different corn stover components, and gas residence time on torrefaction of corn stover. Energies, 5(4): 1199–1214. https://doi.org/10.3390/en5041199

Medina, E., C. Paredes, M. A. Bustamante, R. Moral and J. Moreno-Caselles, 2012. Relationships between soil physico-chemical, chemical and biological properties in a soil amended with spent mushroom substrate. Geoderma, 173–174: 152–161. https://doi.org/10.1016/j.geoderma.2011.12.011

Melanouri, E.-M., M. Dedousi, and P. Diamantopoulou, 2022. Cultivating *Pleurotus ostreatus* and Pleurotus eryngii mushroom strains on agro-industrial residues in solid-state fermentation. Part

I: Screening for growth, endoglucanase, laccase and biomass production in the colonization phase. Carbon Resour. Convers., 5(1): 61–70. https://doi.org/10.1016/j.crcon.2021.12.004

Miklavčič Višnjevec, A., P. Baker, A. Charlton, D. Preskett, K. Peeters, Č. Tavzes, K. Kramberger and M. Schwarzkopf, 2020. Developing an olive biorefinery in Slovenia: Analysis of phenolic compounds found in olive mill pomace and wastewater. Molecules, 26(1): 7. https://doi.org/10.3390/molecules26010007

Miller, R. and D. Horneck, 1997. Determination of total nitrogen in plant tissue. Handbook of Reference Methods for Plant Analysis. https://doi.org/10.1201/9781420049398.ch9

Moonmoon, M., N. J. Shelly, Md. A. Khan, Md. N. Uddin, K. Hossain, M. Tania and S. Ahmed, 2011. Effects of different levels of wheat bran, rice bran and maize powder supplementation with saw dust on the production of shiitake mushroom (*Lentinus edodes* (Berk.) Singer). Saudi J. Biol. Sci., 18(4): 323–328. https://doi.org/10.1016/j.sjbs.2010.12.008

Nelson, D.W. and L.E. Sommers, 1996. Total carbon, organic carbon, and organic matter. In Methods of Soil Analysis (eds: D.L. Sparks, A.L. Page, P.A. Helmke, R.H. Loeppert, P.N. Soltanpour, M.A. Tabatabai, C.T. Johnston and M.E. Sumner). https://doi.org/10.2136/sssabookser5.3.c34

Nunes, M. A., J. D. Palmeira, D. Melo, S. Machado, J. C. Lobo, A. S. G. Costa, R. C. Alves, H. Ferreira, and M. B. P. P. Oliveira, 2021. Chemical composition and antimicrobial activity of a new olive pomace functional ingredient. Pharmaceuticals, 14(9): 913. https://doi.org/10.3390/ph14090913

Oliveira Vieira, V., A. Almeida Conceição, J. Raisa Barbosa Cunha, A. Enis Virginio Machado, E. Gonzaga de Almeida, E. Souza Dias, L. Magalhães Alcantara, R. Neil Gerard Miller and F. Gonçalves de Siqueira, 2022. A new circular economy approach for integrated production of tomatoes and mushrooms. Saudi J. Biol. Sci, 29(4): 2756–2765. https://doi.org/10.1016/j.sjbs.2021.12.058

Omoba, O., R. Obafaye, S. Salawu, A. Boligon and M. Athayde, 2015. HPLC-DAD phenolic characterization and antioxidant activities of ripe and unripe sweet orange peels. Antioxidants, 4(3): 498–512. https://doi.org/10.3390/antiox4030498

Palmieri, G., P. Giardina, C. Bianco, A. Scaloni, A. Capasso and G. Sannia, 1997. A novel white laccase from *Pleurotus ostreatus*. J. Biol. Chem., *272*(50): 31301–31307. https://doi.org/10.1074/jbc.272.50.31301

Pathak, P. D., S A. Mandavgane and B. D. Kulkarni, 2017. Fruit peel waste: characterization and its potential uses. Curr. Sci., 113- 444-454. Doi: 10.18520/cs/v113/i03/444-45

Pine, L., P. S. Hoffman, G. B. Malcolm, R. F. Benson and M. G. Keen, 1984. Determination of catalase, peroxidase, and superoxide dismutase within the genus Legionella. J. Clin. Microbiol., 20(3): 421–429. https://doi.org/10.1128/jcm.20.3.421-429.1984

Podgornik, M., M. Bučar-Miklavčič, A. Levart, J. Salobir, V. Rezar and B. Butinar, 2022. Chemical characteristics of two-phase olive-mill waste and evaluation of their direct soil application in humid Mediterranean regions. Agronomy, 12(7): 1621. https://doi.org/10.3390/agronomy12071621

Rhoades, J. D. 2018. Salinity: Electrical Conductivity and Total Dissolved Solids. Methods of Soil Analysis, 417–435. https://doi.org/10.2136/sssabookser5.3.c14

Ribeiro, T. B., A. L. Oliveira, C. Costa, J. Nunes, A. A. Vicente and M. Pintado, 2020. Total and sustainable valorisation of olive pomace using a fractionation approach. Appl. Sci., 10(19): 6785. https://doi.org/10.3390/app10196785

Rusydi, A. F., 2018. Correlation between conductivity and total dissolved solid in various type of water: A review. IOP Conf. Ser.: Earth Environ. Sci, 118: 012019. https://doi.org/10.1088/1755-1315/118/1/012019

Sarijeva, G., M. Knapp, and H. K. Lichtenthaler, 2007. Differences in photosynthetic activity, chlorophyll C and carotenoid levels, and in chlorophyll fluorescence parameters in green sun and shade leaves of Ginkgo and Fagus. J. Plant Physiol., 164(7): 950–955. https://doi.org/10.1016/j.jplph.2006.09.002

Shariff, A., N. S. Mohamad Aziz, N. I. Ismail and N. Abdullah, 2016. Corn cob as a potential feedstock for slow pyrolysis of biomass. J. Phys. Sci., 27(2): 123–137. https://doi.org/10.21315/jps2016.27.2.9

Sharma, P., Jha, A. B., R. S. Dubey and M. Pessarakli, 2012. Reactive oxygen species, oxidative damage, and antioxidative defense mechanism in plants under stressful conditions. J. Bot., 2012: 1–26. https://doi.org/10.1155/2012/217037

Sultana, S. 2020. Nutritional and functional properties of *Moringa oleifera*. Metab. Open, 8: 100061. https://doi.org/10.1016/j.metop.2020.100061

Tabatabai, M. A. and J. M. Bremner, (1969). Use of p-nitrophenyl phosphate for assay of soil phosphatase activity. Soil Biol. Biochem., 1(4): 301–307. https://doi.org/10.1016/0038-0717(69)90012-1

Téllez-Téllez, M., F. J. Fernández, A. M. Montiel-González, C. Sánchez, and G. Díaz-Godínez, 2008. Growth and laccase production by *Pleurotus ostreatus* in submerged and solid-state fermentation. Appl. Microbiol. Biotechnol., 81(4): 675–679. https://doi.org/10.1007/s00253-008-1628-6

Thomas, G. W., 2018. Soil pH and Soil Acidity. Methods of Soil Analysis, 475–490. https://doi.org/10.2136/sssabookser5.3.c16

Umor, N. A., S. Ismail, S. Abdullah, M. H. R. Huzaifah, N. M. Huzir, N. A. N. Mahmood and A. Y. Zahrim, 2021. Zero waste management of spent mushroom compost. J. Mater. Cycles Waste Manage., 23(5): 1726–1736. https://doi.org/10.1007/s10163-021-01250-3

United nation data base, 2023. http://data.un.org/Default.aspx. http://data.un. org/Data .aspx?d =EDA TA andf=cmID%3aBS%3btrID%3a01

USDA FAS, The U.S. Department of Agriculture's Foreign Agricultural Service, world agriculture production, 2023. https://apps.fas.usda.gov/psdonline/circulars/production.pdf

Vamanu, E., 2012. Biological activities of the polysaccharides produced in submerged culture of two edible *Pleurotus ostreatus* mushrooms. J. Biomed. Biotechnol., 2012: 1–8. https://doi.org/10.1155/2012/565974

Viniegra-González, G., E. Favela-Torres, C. N. Aguilar, S. de J. Rómero-Gomez, G. Díaz-Godínez, and C. Augur, 2003. Advantages of fungal enzyme production in solid state over liquid fermentation systems. Biochem. Eng. J., 13(2–3): 157–167. https://doi.org/10.1016/s1369-703x(02)00128-6

Wagdy, S. M., S. H. Mohamed, and F. S. Taha, 2011. Solubility pattern of simmondsins, proteins and phenolics of defatted jojoba meal. Am. J. Food Technol., 6(11): 963–973. https://doi.org/10.3923/ajft.2011.963.973

Wise, L. E., and E. K. Ratliff, 1947. Quantitative isolation of hemicelluloses and summative analysis of wood. Anal. Chem., 19(7), 459–462. https://doi.org/10.1021/ac60007a010

Wolinska, A., and Z. Stepniewsk, 2012. Dehydrogenase activity in the soil environment. Dehydrogenases. https://doi.org/10.5772/48294

Xu, J. Z., J. L. Zhang, K. H. Hu and W. G. Zhang, 2012. The relationship between lignin peroxidase and manganese peroxidase production capacities and cultivation periods of mushrooms. Microb. Biotechnol., 6(3): 241–247. https://doi.org/10.1111/j.1751-7915.2012.00365.x

Zhang, R., X. Li and J. G. Fadel, 2002. Oyster mushroom cultivation with rice and wheat straw. Bioresour. Technol., 82(3): 277–284. https://doi.org/10.1016/s0960-8524(01)00188-2

Zhao, X., X. Sui, L. Zhao, X. Gao, J. Wang, X. Wen and Y. Li, 2022. Morphological and physiological response mechanism of lettuce (*Lactuca sativa* L.) to consecutive heat stress. Sci. Hortic., 301: 111112. https://doi.org/10.1016/j.scienta.2022.111112

Zheng, R., S. Su, J. Li, Z. Zhao, J. Wei, X. Fu and R. H. Liu, 2017. Recovery of phenolics from the ethanolic extract of sugarcane (*Saccharum officinarum* L.) baggase and evaluation of the antioxidant and antiproliferative activities. Ind. Crops Prod., 107: 360–369. https://doi.org/10.1016/j.indcrop.2017.05.050

Zied, D. C., C. G. de Abreu, L. da S. Alves, E. P. Prado, A. Pardo-Gimenez, P. C. de Melo and E. S. Dias, 2021. Influence of the production environment on the cultivation of lettuce and arugula with spent mushroom substrate. J. Environ. Manage., 281: 111799. https://doi.org/10.1016/j.jenvman.2020.111799