Evaluation of oyster mushroom (Pleurotus ostreatus) cultivation using different organic substrates
Elattar A. ¹, Shimaa M. Hassan ² and Awd-Allah Sh. ³

ABSTRACT
Mushrooms can be considered as functional foods that can provide health benefits beyond the conventional supplements they contain. In the current study, oyster mushroom was grown using various agricultural wastes, including wheat straw (W.S), rice straw (R.S), saw dust (S.D) and water hyacinth (W.H), either single or mixed with wheat straw (R.S+W.S, S.D+W.S and W.H+W.S) at a ratio of 1:1 (w/w), in order to determine their significance on yield, composition and consumer acceptance. The experiments were conducted during the winter season (September to December and January to April) 2017/2018 at Agricultural Research., elsabahia, Alexandria, Egypt. Results revealed that, rice straw + wheat straw (R.S+W.S) and single rice straw (R.S) produced the highest mushroom yield from the harvesting periods (7600 g and 6650 g respectively). For freeze-dried powder, both chemical and nutritional values were examined, comparing between treatments mentioned above. The product grown on a mixture of rice straw and wheat straw had the highest yield score. It showed to be a rich source of protein, minerals and fibres. It could be approved that oyster mushroom developed on blend of rice straw and wheat straw is nutritious as well as a rich source in pharmaceutical-type products. In this study, we attempt to recognize the alternative or mixture of substrates from various agricultural wastes and to evaluate the yield and quality of oyster mushroom (Pleurotus ostreatus). Using the best mushroom extract as prebiotic in fermented dairy products is recommended as trend that could contribute to innovative functional foods.

Key words: Agriculture wastes, Biochemical tests, Oyster mushroom (Pleurotus ostreatus).

INTRODUCTION
Oyster mushrooms have a delicate surface and taste. The majority of consumable mushrooms may have the most shading decent variety: white, yellow, pink, dim, dark colored, and dark clam mushrooms (Pleurotus ostreatus) are normal and common development. The particular flavor or clam mushrooms make them a wonderful backup for fish and shellfish, despite the fact that they combine well with various meats such as chicken. Oyster mushroom fresh fruiting bodies show a high moisture content (90 %), where both dry and fresh oyster mushrooms are rich in carbohydrates (57.6 %), protein (29.2 %), fat (2.1 %), fibre (8.2 %) and ash (9.8 %). Therefore, oyster mushroom is a consumable mushroom, it contains sufficient measure of phosphorous, iron, protein, lipid, riboflavin and thiamine, also known as the meat of the veggie lover (Khan et al. 1981). Mushroom proteins are considered to be moderate between vegetable and animal proteins. The essential amino acids of the human body are found in the oyster mushroom (Kaushlesh et al. 2012). Pleurotus ostreatus contains numerous basic amino acids such as methionine, isoleucine, lysine and glutamic acids. It is also rich in physiologically meaningful primary and secondary metabolites and chemical elements. One hundred grams of fresh fruiting bodies contain 15 percent of vitamin C’s recommended daily intake, 40 percent of niacin, riboflavin, and thiamin, and 0.5 mg of vitamin B12. This species also has a high oleic acid content (40 %), linolenic acid (55 %) (Piska et al. 2017). The minerals, for example, ferrous sulfate, phosphorus, sodium and calcium are available in oyster mushroom (Pandey and Ghosh 1996). It is used for food as well as medicine. Mushrooms have a high dietary advantage and a sparkling taste. Weight control plans are reasonable due to their low caloric value. Pleurotus ostreatus produces medicinal and pharmacological metabolites of antimicrobial, immunostimulant, antioxidant and antitumor interest (Elmastas et al. 2007). Source of substrate, spawn quality, strain and compost affect the execution and development of oyster mushrooms (Royse et al. 2004). The genus Pleurotus is notable for the transformation of substrates into mushrooms. In Egypt, agricultural wastes are about 35 million tons between plant and animal residues. The utilized waste is about 7 million tons for feed and 4 million tons for organic fertilizer but 12

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million tons of plant wastes are still useless (The Ministry of Environment report – Egypt 2014). The recycling of this waste leads to reduce rates of emerging environmental pollution from the burning of plant residues and escalating carbon dioxide and other gases causing global warming high temperature. It leads to increase the high temperature on the surface of the earth and emergence of the black cloud. Also, using of agricultural wastes in the production of mushroom leads to cut the life cycle of many insects, as well as resistance to rodents and rats which found during rice straw storage. Water hyacinth is one of the environmental pollutants as it spreads in the Nile River. It consumes high amounts of water in addition to absorb large amounts of soluble oxygen in the water, leading to many risks to the environment. Many researchers have shown that Pleurotus can be effectively developed on practically all farming squanders. Wheat, rice, maize, sugarcane bagasse and sorghum straw supported the great development of the mushroom and the rapid growth of mycelia. The structure of the substrates is also important because it helps to penetrate mycelium. Therefore, the objective of this research is to evaluate the organic agriculture wastes as a cultivation media to produce high yield and high quality of oyster mushroom. So, the results of this study provided more information to select the best economic and environmental conditions to produce high quality and quantity of mushrooms. This will allow the people at poor villages to produce high quality and quantity of mushroom with low production cost which will increase them incomes.

MATERIALS AND METHODS

The experiments were conducted during the winter season (September to December and January to April) of 2017/ 2018 at Agricultural Research., elsabahia, Alexandria, EGYPT.

Oyster mushroom cultivation

Substrate preparation

Agricultural wastes including wheat straw (W.S), rice straw (R.S), saw dust (S.D) and water hyacinth (W.H), either single or mixed with wheat straw (R.S+W.S, S.D+W.S and W.H+W.S) were evaluated to determine their effect on mass production and composition of oyster mushroom (Pleurotus ostreatus). The ratio of each agro-waste and wheat straw was 1: 1 (wheat straw: agro-waste, w/w).

Inoculation, incubation, and culture conditions

The agro-wastes or their mixture (W.S, R.S, S.D, W.H, R.S+W.S, S.D+W.S and W.H+W.S) were immersed in water for 1-2 hours, then washed 2 or multiple times in clean water to adjust the moisture content to 65%, and CaCO₃ was mixed at 0.2% of the mixture (w/w). Substrates were filled into polyethylene packs and sterilized at 121°C for 80 min. After the substrates were chilled off to room temperature, they were inoculated with oyster mushroom spawning at a rate of 5% of the substrates wet weight. The autoclaved substrates and spawn’s mixtures were placed in three layers (50 gm of spawn in each layer), bottom, middle and surface of the substrate when the mixtures were filled into polyethylene packs. In this experiment using Completely Randomized Design (CRD) with three replicates, two duplicate polyethylene packs for the same substrate have been used for each replicate During the first three weeks, the inoculated bags were then placed under 80–95 % relative humidity with complete darkness in a spawn running room at 20–25°C until the substrates were fully colonized with mycelium. To encourage primordial starting, packs were punctured (shape) using a four-sided clean knife. The runtime generated was recorded to add up to the substrate's mycelium colonization (Oei and van Neuenhuijzen 2005).

Harvesting and parameters

When the tops developed completely and the fruiting bodies began to curl up, mushrooms were collected from the substrate. The mushroom clusters were weighed and several parameters were evaluated: first initiation; (time between the day of inoculation and the day of mycelium appearance), earliness harvest; (time between the day of inoculation and the day of first gathering) and biological efficiency (percentage yield of fresh mushroom over the substrate's dry weight) (Yang et al. 2013).

Preparation of dehydrated mushroom powder (DMP)

After cutting fresh mushrooms into 2 mm thick slices, they spread over aluminum trays in a single layer and kept overnight at -80°C, then subjected in freeze-dryer Zirbus (Vaco-5-II Germany). The freeze dryer was programmed to operate primary drying cycle for 20 h at 0°C shelf temperature and 0.6 mbar chamber pressure, followed by secondary drying cycle at 15°C shelf temperature for 2 h and 0.4-0.5 mbar chamber pressure. The freeze-dried mushroom was electrically grounded to obtain dehydrated mushroom powder (DMP). The dehydrated mushroom powder was packed, sealed in plastic bags under vacuum and stored in a refrigerator (4°C) until used.

Chemical composition of oyster mushroom.

The dehydrated mushroom powder (DMP) samples have been chemically analyzed for dry matter (DM; AOAC 2006, ID number 930.15), organic matter (OM; ID number 942.05) and crude protein (CP; as 6.25 below N; ID number 954.01). ANKOM 220 Fiber
Analyzer unit (ANKOM Technology Corporation, Macedon, NY, USA) was used to analyze neutral detergent fiber (NDF), crude fibre in addition to acid detergent fiber (ADF) according to Van Soest et al. (1991). Lignin (sa) content was sequentially determined in the same sample by solubilizing ADF with 720 mL / L sulfuric acid (Robertson and Van Soest 1981). Hemicellulose, cellulose, total available carbohydrate and energy were calculated as mentioned below:

\[ \text{hemicellulose} = \text{NDF} + \text{ADF} \]

\[ \text{NDF: Neutral detergent fibre, ADF: Acidic detergent fibre.} \]

\[ \text{cellulose} = \text{NDF} - \text{lignin} \]

\[ \text{Total carbohydrate} \% = [100 - (\text{moisture + total ash + fibre + protein + fat})] \]

\[ \text{Energy (Kcal)} = [(\text{protein } \times 4) + (\text{carbohydrate } \times 4) + (\text{fat } \times 9)] \]

**Amino acids content of DMP**

Based on the method described by Pellet and Young (1980), the amino acid composition of mushroom was determined, using amino acid analyzer (LC 3000 Eppendorf) at Dessert Research Center's, Central Lab. Cairo.

**Fatty acids profile analysis**

Fat content was extracted from mushroom samples according to Folch et al. (1957). Two drops of the remaining oil were dissolved in 5 ml benzene (GC grade), 7mL GC solvent (1% H2SO4 in methanol) were added for the preparation of fatty acid methyl ester, then the mixture was heated in the oven at 90°C for 90 min. Two mL of distilled water and shook well until the mixture was separated into two layers. The upper layer was transferred into sodium sulfate to eliminate excess moisture. The filtrate was passed through a 0.22μl microfilter to be ready for injection in the GC column. A split injector and FID detector from ACME model 6100 GC (Young LIN Instrument Co., Korea) were used to complete the gas chromatographic investigation. Nitrogen was used as a carrier gas of 0.5 ml / min. The components were separated on 30 m SP-2380 fused-silica capillary column with 0.25 mm ID and 0.2 μm film thickness (Supelco, Bellefonte, PA). The detector temperature was set at 260°C, the injector temperature was set at 220°C and in split mode (1:80 split ratio). The column was initially maintained for 5min at 140°C and then raised to 240°C at rate of 4°C / min (modified method of Schumann and Siekmann 2000).

**Minerals content of DMP**

Mineral content and trace elements were conducted according to ASTM (2002) using inductively coupled Argon plasma, iCAP 6500 Duo, Thermo Scientific, England. One thousand mg/L multi-element certified standard solution, Merck, Germany was used as stock solution for instrument standardization.

**Vitamins content of DMP**

**Extraction of vitamin (B)**

Vitamin B complex was extracted according to the method described in AOAC International (1990).

**Determination of riboflavin and niacin using HPLC**

A reverse phase HPLC technique using HPLC ultimate 3000, UK, determined the vitamins. The following conditions were used to separate riboflavin and niacin: according to Ismail and Fun (2003):

- Methanol-water-acetic acid glacial (65:35:0.1) was used as a mobile phase, in a flow rate of 1 mL/min, using UV detector (280 nm).

Comparison of retention time and spiking test with the riboflavin and niacin standard (Sigma, Co. Chemical, St. Louis, USA) was used to identify the riboflavin and niacin peak. The final concentration of the standard was represented in 100 μg/mL.

**Statistical analysis**

All data recorded throughout the study were exposed to the analysis of variance techniques based on the design used by the Windows CoStat software package. Treatment means were separated and compared at a meaning level of 0.05 by the L.S.D test (Snedecor and Cochran, 1980). The winter error for the character of the two study dates (September through December and January through April) was homogeneous, as determined by the error homogeneity test (Hartley 1950), so the data were combined over the two dates.

**RESULTS AND DISCUSSIONS**

**Yield and biological efficiency (BE) of Pleurotus ostreatus**

Oyster mushroom experiments growing on seven different agricultural waste substrates including wheat straw (W.S), rice straw (R.S), saw dust (S.D) and water hyacinth (W.H), either single or mixed with wheat straw (W.S) 1:1 (wheat straw: agro-waste) (w/w). In Table (1) the first initiation period on substrates S.D+W.S, R.S and R.S+W.S were significantly shorter (28, 29 and 29 days, respectively) than the other substrates. On the other hand, the longest period of appearing mycelium recorded by water hyacinth (W.H) was 38 days. These findings were consistent with Hassan (2005) as the oyster mushroom cultivated on rice straw and a combination of rice straw with wheat straw provided a shorter period of mycelium appearance (28 and 29 days, respectively).

The earliness harvest of oyster mushroom ranged between 33-45 days, depending on the substrate used. Our results showed that the first harvest of oyster
mushroom grown on a mixture of saw dust and wheat straw (S.D+W.S), rice straw (R.S) and a mixture of rice straw and wheat straw (R.S+W.S) was lower than the other samples (33, 34 and 34 days respectively, Table 1). Along these lines, this is a favorable position to deliver mushroom in brief time and could be a time economy.

The yield is one of the mushroom growers' main targets. All the oyster mushrooms grown on various substrates showed significant differences in mushroom yield performance (Tables 1 and 2). Therefore, use of a diversity of the substrates is essential. In this study, the amount of mushroom yield using a mixture of rice straw and wheat straw (R.S+W.S) appeared a significantly highest mushroom yield (7600 g) throughout the three harvesting periods. The highest yield was followed by, oyster yields using rice straw alone (R.S) during the three harvesting periods (6650 g). On the other hand, the lowest yield (3055 g) was noticed in cultivated mushroom using water hyacinth (W.H) throughout the three harvesting periods. Commonly, in this study it was observed the trend gradually decreased from the first till the third harvesting periods for all the produced mushroom (Table 2).

In term of biological efficiency (BE), mushroom produced from rice straw + wheat straw substrate (R.S+W.S) followed by rice straw (R.S) had higher values than the other substrates (126.7 and 110.8%, respectively). In general, substrates gave the higher yield also gave the higher value of BE. Whereas, substrate 100% water hyacinth (W.H) followed by saw dust (S.D) showed the lowest mushroom yield, as well as the lowest BE (Table 2). On the other hand, it was observed that the combination of the previous substrates (water hyacinth and saw dust) with wheat straw at (1: 1) ratio (W.H+W.S and S.D+W.S) improved the BE (50.9% to 83.2% and 66.7% to 92.5%, respectively).

Table 1. Effect of substrate on oyster mushroom production

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<td>First initiation (day)</td>
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<td>Earliness harvest (day)</td>
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<td>34</td>
<td>38</td>
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<td>Total fresh weight (g)</td>
<td>5669</td>
<td>6650</td>
<td>7600</td>
<td>4000</td>
<td>5550</td>
<td>3055</td>
<td>4990</td>
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Values followed by the same values alphabetical letter(s) in common, within a particular group of means in each character, do not significantly differ, using Revised L.S.D test at 0.05 level of probability

Table 2. Production yield of oyster mushroom during 3 harvesting periods

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<td>production weight (g)</td>
<td>2399</td>
<td>3210</td>
<td>3320</td>
<td>1650</td>
<td>2720</td>
<td>1415</td>
<td>2360</td>
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<td>1st harvest period</td>
<td></td>
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<tr>
<td>production weight (g)</td>
<td>1850</td>
<td>2100</td>
<td>2640</td>
<td>1250</td>
<td>1580</td>
<td>900</td>
<td>1560</td>
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<tr>
<td>2nd harvest period</td>
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<tr>
<td>production weight (g)</td>
<td>1420</td>
<td>1340</td>
<td>1640</td>
<td>1100</td>
<td>1250</td>
<td>740</td>
<td>1070</td>
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<tr>
<td>3rd harvest period</td>
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<tr>
<td>Biological efficiency (BE) %</td>
<td>94.4</td>
<td>110.8</td>
<td>126.7</td>
<td>66.7</td>
<td>92.5</td>
<td>50.9</td>
<td>83.2</td>
</tr>
</tbody>
</table>

Values followed by the same alphabetical letter(s) in common, within a particular group of means in each character, do not significantly differ, using Revised L.S.D test at 0.05 level of probability.

a,b,c,... Mean values in the same row between different treatments marked with unlike letters are significantly different (p<0.05)

W.S. mushroom cultivated on wheat straw, R.S. mushroom cultivated on rice straw, R.C+W.S. mushroom cultivated on a mixture of rice straw and wheat straw, S.D .mushroom cultivated on saw dust, S.D+W.S. mushroom cultivated on a mixture of saw dust and wheat straw, W.H. mushroom cultivated on water hyacinth, W.H+W.S. mushroom cultivated on a mixture of water hyacinth and wheat straw
Our results were compatible with Fawzi (2016) as the total yield was in highest levels in oyster mushroom cultivated on rice straw substrate followed by mixture of rice plus wheat straw (3500 and 3360 g/4kg substrate, respectively) also, their biological efficiency were 87 and 84%, respectively.

Differences in yield and BE of oyster mushroom grown on different types of substrates were due to differences in the physical and chemical composition of substrate formulas such as cellulose/lignin ratio and mineral content, pH, EC of substrate, in particular C/N ratio. One of the factors influencing overall yield and BE compared to other substrates was low substrate nitrogen (Hoa et al. 2015). An easier way to obtain sugar from cellulosic substances is causing the increase in mushroom yield in rice straw (Ponmurugan et al. 2007). *Pleurotus* specie therefore requires carbon, nitrogen and inorganic compounds as their nutritional sources. The main nutrients are less nitrogen and more carbon, so materials containing cellulose, hemicellulose, and lignin (i.e. rice and wheat straw, cotton, sawdust, waste paper, leaves, and residue of sugarcane) can be used as mushroom substrates (Chang and Miles 1989). Oyster mushroom may grow on a wide variety of substrates. The yield and quality of oyster mushrooms, however, depend on the chemical and nutritional content of substrates (Badu et al. 2011 and Patil et al. 2010).

**Chemical Composition of DMP**

Table (3) presented fundamental nutritional characteristics; ash, fibre, protein, fat and carbohydrate content, in addition to energy value for 100g of oyster mushrooms grown on various substrates. The moisture content of fried oyster mushroom did not affect with different substrates which was (6.41-12.49%). The highest moisture content of the oyster mushroom was due to the water holding capacity of the substrate. The result was very close to the stated value mentioned by Kurtzman (2005) and Ahmed et al. (2009), who reported that species grown on various agro-wastes for *Pleurotus*. Mushroom age, growing environments, mushroom strains, and post-harvest environments also influenced moisture content (Kurtzman 2005).

The study indicated that the oyster mushrooms grown on all substrates are quite rich in protein, carbohydrates and fibre content making them excellent foods that can be used in low caloric diets. Mushroom protein on a dry weight basis ranged from 19.21 to 29.76%. This value was somewhat similar to the range reported by Kurtzman (2005) in which the dry matter-based protein in the oyster mushroom ranged from 20 to 40%. The highest mushroom protein (29.76%) was recorded from mushrooms grown on water hyacinth (W.H). While moderate protein values were recorded from mushrooms grown in rice straw (R.S) and rice straw+wheat straw (R.S+W.S) (21.41 and 19.90%, respectively). Differences in the protein content of mushrooms grown on different substrates may be due to substrates’ varying nitrogen content. Mushroom protein is an easily digested form and is also better than many legumes such as soybeans and peanuts and vegetable protein-producing foods (Chang and Buswell 1996; Chang and Mshigeni 2001).

In the cultivated oyster mushroom, the content of ether extract and fibre ranged from 3.12% to 5.64% and 10.095% to 13.38% respectively. The highest fibre content was obtained from the mushroom grown on water hyacinth (W.H). Whereas the moderate fibre contents were noticed in mushroom grown on rice straw (R.S) and mixture of rice straw and wheat straw (10.55 and 10.095%). The ether content of the extract obtained in the study was higher than that reported by Wang et al. (2000). While the fibre content was comparable to that of Yehia (2012). For mushroom grown on water hyacinth (W.H) and rice straw (R.S), the carbohydrate content of oyster mushroom ranged from 36.688% to 50.968%, respectively. Patil et al. (2010) reported that the *P. ostreatus* content of carbohydrates ranged from 50.50 to 55.33% grown on paddy straw, soybean straw and wheat straw. However, Sharma et al. 2013's findings, were 30.24–42.26% of *P. ostreatus* grown on various substrates. Substrate not only affected protein, carbohydrate and fat, but also influenced total oyster mushroom energy (Table 3). For oyster mushroom, the total energy contribution of the samples ranged from 296.23 to 327.69 kcal/100 g dry weights. Manzi et al. (2001) reported that *P. ostreatus* energy contribution was 300 kcal/100gm, but obtained energy values in kcal / 100 g were somewhat higher than these findings.

**Amino acid profile of DMP**

Mushrooms are considered a good source of protein and amino acids as a consequence. The amino acid profile (mg/100 g) of *P. ostreatus* grown on various substrates has therefore been determined (Table 4). In the first picking of *P. ostreatus*, a number of 17 amino acids were estimated, with different levels. The highest values were observed for glutamic acid (8.68–21.02 mg/100 g), aspartic acid (3.36–14.32 mg/100 g), alanine (5.60–12.05 mg/100 g), leucine (8.07–11.74 mg/100 g), lysine (6.63–9.88 mg/100 g), valine (5.51–9.55 mg/100 g), proline (6.54–8.87 mg/100 g) and glycine (5.25–8.50 mg/100 g). While the lowest values recorded by cysteine (0.03-0.28 mg/100 g) and methionine (1.1-1.61 mg/100 g). Water hyacinth combination with wheat straw (W.H + W.S) improved several *P. ostreatus* amino acids such as aspartic, threonine, serine, glutamic, proline, glycine,
Table 3. Chemical composition of dried oyster mushroom cultivated on different substrates

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<tr>
<td>Moisture content</td>
<td>8.62 e</td>
<td>6.41 g</td>
<td>10.01 b</td>
<td>9.12 c</td>
<td>12.49 a</td>
<td>8.92 d</td>
<td>8.55 f</td>
</tr>
<tr>
<td>Dry matter</td>
<td>91.38 e</td>
<td>93.59 a</td>
<td>89.99 f</td>
<td>90.88 e</td>
<td>87.51 g</td>
<td>91.08 d</td>
<td>91.45 b</td>
</tr>
<tr>
<td>Organic matter</td>
<td>84.71 b</td>
<td>87.17 a</td>
<td>84.10 e</td>
<td>84.19 d</td>
<td>80.67 g</td>
<td>83.21 f</td>
<td>84.41 c</td>
</tr>
<tr>
<td>Crude protein</td>
<td>19.21 f</td>
<td>21.41 d</td>
<td>19.90 f</td>
<td>27.98 b</td>
<td>21.34 e</td>
<td>29.76 a</td>
<td>26.40 c</td>
</tr>
<tr>
<td>Ether extract</td>
<td>4.016 a</td>
<td>4.242 a</td>
<td>5.642 a</td>
<td>3.964 a</td>
<td>3.852 a</td>
<td>3.382 a</td>
<td>3.12 a</td>
</tr>
<tr>
<td>Ash</td>
<td>6.67 e</td>
<td>6.42 f</td>
<td>5.89 g</td>
<td>6.69 d</td>
<td>6.84 c</td>
<td>7.87 a</td>
<td>7.04 b</td>
</tr>
<tr>
<td>NDF</td>
<td>59.35 a</td>
<td>56.98 c</td>
<td>58.06 b</td>
<td>52.20 c</td>
<td>48.69 g</td>
<td>50.98 f</td>
<td>53.74 d</td>
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<td>ADF</td>
<td>27.71 c</td>
<td>28.39 b</td>
<td>28.52 a</td>
<td>23.65 f</td>
<td>23.75 c</td>
<td>22.84 f</td>
<td>24.56 d</td>
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<tr>
<td>Lignin</td>
<td>0.29 e</td>
<td>0.42 d</td>
<td>4.85 a</td>
<td>0.55 c</td>
<td>0.25 f</td>
<td>0.55 c</td>
<td>0.75 b</td>
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<td>Hemicellulose</td>
<td>31.64 a</td>
<td>28.59 d</td>
<td>29.54 b</td>
<td>28.55 c</td>
<td>24.94 f</td>
<td>28.14 f</td>
<td>29.18 c</td>
</tr>
<tr>
<td>Cellulose</td>
<td>27.42 b</td>
<td>27.97 a</td>
<td>23.67 d</td>
<td>23.10 f</td>
<td>23.50 e</td>
<td>22.29 f</td>
<td>23.81 c</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>12.22 ab</td>
<td>10.55 b</td>
<td>10.095 b</td>
<td>10.8 ab</td>
<td>11.2 ab</td>
<td>13.38 a</td>
<td>12.484 ab</td>
</tr>
<tr>
<td>Total available carbohydrates</td>
<td>49.264 b</td>
<td>50.968 a</td>
<td>48.463 c</td>
<td>41.446 f</td>
<td>44.278 d</td>
<td>36.688 g</td>
<td>42.406 c</td>
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<tr>
<td>Energy</td>
<td>310.04 d</td>
<td>327.69 a</td>
<td>324.23 b</td>
<td>313.38 c</td>
<td>297.14 f</td>
<td>296.23 g</td>
<td>303.304 c</td>
</tr>
</tbody>
</table>

Values followed by the same alphabetical letter(s) in common, within a particular group of means in each character, do not significantly differ, using Revised L.S.D test at 0.05 level of probability.

alanine, cysteine, valine, methionine, isoleucine, and leucine. Oyster mushroom grown on rice straw (R.S) and a mixture of rice straw and wheat straw (R.C + W.S) was a moderate value of all determined amino acids compared to the other studied substrates. Pleurotus species are rich in glutamic acid, aspartic acid, lysine, leucine and threonine (Mdachi et al. 2004 and Kim et al. 2009). The differences in amino acids found in the same mushroom species may be a consequence of the genetic variation and cultivation process applied in commercial practices which was also revealed by Mendez et al. (2005).

Fatty acid profile of DMP

Figure (1) showed the results of the studied mushroom composition of fatty acids, total saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA). PUFA was the main group of fatty acids compatible with other studies in all mushroom samples (D’iez and Alvarez 2001). The major fatty acid found was linoleic acid (C18:2), which contributed to PUFA’s prevalence. The most abundant MUFA in all the samples was oleic acid (C18:1), while the major SFA was palmitic acid (C16:0). In all the seven mushrooms tested, at least 71.41 and 27.6% of the total fatty acids are found to be unsaturated and saturated, respectively. The results of this study are consistent with linoleic (C18:2) and oleic (C18:1) acids in P. ostreatus lipids, reported by Pedneault et al. (2007) and Barros et al. (2008). They are also common precursors and intermediates in the biosynthesis and metabolism of other fatty acids. It should be noticed that unsaturated fatty acids are basic and critical for our eating regimen and our health. All the mushrooms analysed contained high content of basic unsaturated fatty acids, cis-linoleic acid, as a source of basic unsaturated fatty acid (i.e. fatty acids that cannot be synthesized by higher animals, especially linoleic acid and fat-soluble vitamins (A, D, E, K). Essential fatty acids are fatty acids must be ingested by humans and other animals because the body requires them for good health but cannot synthesize them (Goodhart and Shils 1980) with high amounts of cis-linoleic acid (18:2) in Pleurotus ostreatus (65.29%). These results were consistent with previous reports that many species of mushrooms had high proportions of unsaturated fatty acids, particularly linoleic acid (Kalac 2009 and Ruess et al. 2002).
Elattar A., Shimaa M. Hassan, et al.: Evaluation of oyster mushroom (Pleurotus ostreatus) cultivation using different...

(a) Wheat straw
(b) Rice straw
(c) Rice straw+wheat straw
(d) Saw dust
Figure 1. Fatty acid profile (%) of *Pleurotus ostreatus* cultivated on different substrates (a - g)

- (e) Saw dust + wheat straw
- (f) Water hyacinth
- (g) Water hyacinth + wheat straw
It is known that linoleic acid is the precursor of 1-octen-3-ol, known as fungal alcohol, which is the main aromatic compound in most fungi and may contribute to the flavour of mushrooms (Maga 1981).

Fortunately, the mushrooms studied detected very low amounts of unsaturated fatty acid trans isomers (0.02–0.12%) (Pelin et al. 2013). A rapidly expanding literature documents the importance of trans fatty acids (TFAs) in human health due to the increased risk of cardiovascular disease where they are negatively correlated with plasma concentrations of HDL-cholesterol and positively correlated with plasma levels of LDL-cholesterol (Minamide and Hammond 1985). It is also important to note that, unlike other fungi (D’iez and Alvarez 2001 and Longvah and Deosthale 1998), no other fatty acids with an odd number of carbon atoms were found in significant amounts.

**Minerals content of DMP**

Dietary minerals are essential for metabolic reactions, healthy bone formation, nerve impulse transmission, water regulation, and salt balance (Kalač and Svoboda 2000). Mushrooms are a good source of minerals needed for human nutrition, so some minerals like iron, zinc, magnesium, potassium and phosphorus have been identified (Table 5). In general, the most abundant minerals in oyster mushroom cultivated on various substrates were magnesium, phosphorus and

### Table 4. Amino acid profile of dried oyster mushroom cultivated on different substrates

<table>
<thead>
<tr>
<th>Substrates</th>
<th>W.S</th>
<th>R.S</th>
<th>R.S+W.S</th>
<th>S.D</th>
<th>S.D+W.S</th>
<th>W.H</th>
<th>W.H+W.S</th>
<th>Estimated A.A requirements mg/kg per day for adults</th>
<th>Essential A.A</th>
<th>Non essential A.A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valine</td>
<td>6.49 f</td>
<td>7.66 d</td>
<td>7.03 e</td>
<td>8.58 b</td>
<td>7.91 c</td>
<td>5.51 g</td>
<td>9.55 a</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methionine</td>
<td>1.10 b</td>
<td>1.39 ab</td>
<td>1.22 b</td>
<td>1.61 a</td>
<td>1.34 ab</td>
<td>1.23 b</td>
<td>1.60 a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isoleucine</td>
<td>5.08 g</td>
<td>5.98 e</td>
<td>5.51 f</td>
<td>6.66 b</td>
<td>6.00 d</td>
<td>6.53 c</td>
<td>7.50 a</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leucine</td>
<td>8.07 f</td>
<td>9.42 d</td>
<td>8.62 c</td>
<td>10.60 c</td>
<td>9.42 d</td>
<td>10.80</td>
<td>11.74 a</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenyl alanine</td>
<td>4.69 g</td>
<td>5.97 e</td>
<td>5.17 f</td>
<td>6.46 c</td>
<td>6.09 d</td>
<td>7.51 a</td>
<td>7.03 b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Histidine</td>
<td>2.99 g</td>
<td>3.59 e</td>
<td>3.31 f</td>
<td>3.99 c</td>
<td>3.64 d</td>
<td>4.72 a</td>
<td>4.69 b</td>
<td>8-12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lysine</td>
<td>6.71 f</td>
<td>7.83 d</td>
<td>6.89 e</td>
<td>8.99 c</td>
<td>6.63 g</td>
<td>9.88 a</td>
<td>9.81 b</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Threonine</td>
<td>3.65 ab</td>
<td>4.33 ab</td>
<td>3.91 ab</td>
<td>4.80 a</td>
<td>4.39 a</td>
<td>1.58 b</td>
<td>5.22 a</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proline</td>
<td>6.54 g</td>
<td>7.45 d</td>
<td>6.73 f</td>
<td>8.15 b</td>
<td>7.42 c</td>
<td>7.77 c</td>
<td>8.87 a</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Glutamic acid</td>
<td>14.37 f</td>
<td>17.90 d</td>
<td>15.92 e</td>
<td>20.95 b</td>
<td>20.93 c</td>
<td>8.68 g</td>
<td>21.02 a</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Glycine</td>
<td>6.12 ab</td>
<td>6.92 ab</td>
<td>5.95 ab</td>
<td>7.94 ab</td>
<td>6.92 ab</td>
<td>5.25 b</td>
<td>8.50 a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alanine</td>
<td>7.85 f</td>
<td>9.65 d</td>
<td>8.59 e</td>
<td>10.88 c</td>
<td>12.05 a</td>
<td>5.60 g</td>
<td>11.75 b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cystine</td>
<td>0.28 a</td>
<td>0.10 e</td>
<td>0.06 f</td>
<td>0.03 g</td>
<td>0.18 b</td>
<td>0.11 d</td>
<td>0.16 c</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tyrosine</td>
<td>1.99 g</td>
<td>2.41 e</td>
<td>2.25 f</td>
<td>2.81 c</td>
<td>2.62 d</td>
<td>3.10 a</td>
<td>2.91 b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serine</td>
<td>2.46 ab</td>
<td>2.76 a</td>
<td>2.51 ab</td>
<td>3.20 a</td>
<td>2.39 ab</td>
<td>0.97 b</td>
<td>3.26 a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspartic acid</td>
<td>10.56 bc</td>
<td>11.61 bc</td>
<td>11.10 bc</td>
<td>12.57</td>
<td>9.41 c</td>
<td>3.36 d</td>
<td>14.32 a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arginine</td>
<td>2.60 ab</td>
<td>2.90 ab</td>
<td>2.75 ab</td>
<td>3.62 ab</td>
<td>2.34 b</td>
<td>4.52 a</td>
<td>3.91 ab</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Values followed by the same alphabetical letter(s) in common, within a particular group of means in each character, do not significantly differ, using Revised L.S.D test at 0.05 level of probability a,b,c,... Mean values in the same row between different treatments marked with unlike letters are significantly different (p<0.05). Amino acid content is represented in mg/g dry weight.

W.S. mushroom cultivated on wheat straw, R.S. mushroom cultivated on rice straw, R.C+W.S. mushroom cultivated on a mixture of rice straw and wheat straw, S.D. mushroom cultivated on saw dust, S.D+W.S. mushroom cultivated on a mixture of saw dust and wheat straw, W.H. mushroom cultivated on water hyacinth, W.H+W.S. mushroom cultivated on a mixture of water hyacinth and wheat straw.

1 Based on highest estimate of requirement to achieve nitrogen balance. Data from several investigators (reviewed in FAO/WHO, 1973).
Table 5. Mineral contents of dried oyster mushroom cultivated on different substrates

<table>
<thead>
<tr>
<th>Substrates</th>
<th>Ca</th>
<th>Co</th>
<th>Cr</th>
<th>Cu</th>
<th>Fe</th>
<th>Mg</th>
<th>Mn</th>
<th>Mo</th>
<th>Ni</th>
<th>V</th>
<th>Zn</th>
<th>P</th>
<th>K</th>
<th>Na</th>
</tr>
</thead>
<tbody>
<tr>
<td>W.S</td>
<td>102.8</td>
<td>0.001</td>
<td>6.86</td>
<td>13.46</td>
<td>79.35</td>
<td>1140.2</td>
<td>4.33</td>
<td>0.001</td>
<td>0.352</td>
<td>0.01</td>
<td>44.47</td>
<td>6548.4</td>
<td>140</td>
<td>7</td>
</tr>
<tr>
<td>R.S</td>
<td>124.7</td>
<td>0.001</td>
<td>1.22</td>
<td>13.27</td>
<td>106.02</td>
<td>1202.1</td>
<td>6.44</td>
<td>0.001</td>
<td>1.899</td>
<td>0.01</td>
<td>46.83</td>
<td>5975.4</td>
<td>160</td>
<td>5</td>
</tr>
<tr>
<td>R.S+W.S</td>
<td>93.8f</td>
<td>0.001</td>
<td>2.27cd</td>
<td>13.14f</td>
<td>66.09f</td>
<td>1189.5f</td>
<td>5.91f</td>
<td>0.001</td>
<td>0.210</td>
<td>0.01</td>
<td>38.84f</td>
<td>5887.4f</td>
<td>150cd</td>
<td>4</td>
</tr>
<tr>
<td>S.D</td>
<td>280.5a</td>
<td>0.001</td>
<td>2.52cd</td>
<td>13.05f</td>
<td>70.61f</td>
<td>1506.3f</td>
<td>6.27f</td>
<td>0.001</td>
<td>0.418</td>
<td>0.234</td>
<td>54.39</td>
<td>10248.4b</td>
<td>180b</td>
<td>3</td>
</tr>
<tr>
<td>S.D+W.S</td>
<td>155.4b</td>
<td>0.001</td>
<td>2.94c</td>
<td>13.20f</td>
<td>250.74a</td>
<td>1515.8</td>
<td>6.71f</td>
<td>0.001</td>
<td>0.429</td>
<td>0.01</td>
<td>53.26</td>
<td>7836.5d</td>
<td>150cd</td>
<td>4</td>
</tr>
<tr>
<td>W.H</td>
<td>142.3c</td>
<td>0.001</td>
<td>10.96a</td>
<td>16.95a</td>
<td>70.32d</td>
<td>1436.2e</td>
<td>7.90a</td>
<td>0.001</td>
<td>0.189</td>
<td>0.01</td>
<td>61.58</td>
<td>10924.4a</td>
<td>200a</td>
<td>4</td>
</tr>
<tr>
<td>W.H+W.S</td>
<td>138.9d</td>
<td>0.001</td>
<td>3.54c</td>
<td>16.49b</td>
<td>69.82d</td>
<td>1295.0d</td>
<td>6.33ab</td>
<td>0.001</td>
<td>0.338</td>
<td>0.01</td>
<td>50.21</td>
<td>9115.8c</td>
<td>180b</td>
<td>4</td>
</tr>
</tbody>
</table>

Values followed by the same alphabetical letter(s) in common, within a particular group of means in each character, do not significantly differ, using Revised L.S.D test at 0.05 level of probability. a,b,c,... Mean values in the same row between different treatments marked with unlike letters are significantly different (p<0.05). Minerals content is represented in mg/Kg dry weight. W.S. mushroom cultivated on wheat straw, R.S. mushroom cultivated on rice straw, R.C+W.S. mushroom cultivated on a mixture of rice straw and wheat straw, S.D .mushroom cultivated on saw dust, S.D+W.S. mushroom cultivated on a mixture of saw dust and wheat straw, W.H. mushroom cultivated on water hyacinth, W.H +W.S. mushroom cultivated on a mixture of water hyacinth and wheat straw.
potassium. Magnesium (1515.6 mg/kg dry weight), recorded the highest values in oyster mushroom grown in combination with saw dust with wheat straw (S.D+W.S) from the first picking. Whereas, rice straw-grown (R.S) oyster mushroom and rice straw mixture with wheat straw (R.S+W.S) represented moderate values of this mineral (1202.1 and 1189.5 mg / kg dry weight, respectively). Potassium and phosphorus were the highest values in oyster mushroom grown on water hyacinth (200 mg/kg dry weight and 10924.4 mg/Kg dry weight, respectively). Peter (1991) agreed with the results obtained in which oyster mushrooms generally contained substantial amounts of phosphorus, magnesium and potassium and lower levels of sodium, iron and zinc. The oyster mushroom grown on rice straw (R.S) and the mixture of rice straw with wheat straw (R.S+W.S) represented moderate values of copper, manganese, potassium and sodium (13.27-13.14, 6.4-5.91, 160-150 and 5-4 mg/Kg dry weight, respectively). There is a good balance between high K content and low Na content, and thus may be involved in curing high blood pressure (Manzi et al. 1999). According to the recommended dietary allowance (National Research Council, 1989), 100g of mushroom could supply all the necessary amounts of phosphorus, iron, magnesium, 8-15% sodium and half potassium and zinc requirements for human diet. In general, in comparison with vegetables, mushroom species provide a reasonable amount of minerals (Guillamón et al. 2010).

**Vitamin B in DMP**

Mushrooms are an important vitamin source. Group B vitamins are abundant, including thiamine (B1), riboflavine (B2), pantothenic acid (B5), folic acid (B9), and other vitamins such as ergosterol, biotin, and tocopherols (Breeen 1990; Mattila et al. 1994 and 2001). Dudka et al. (1992) reported that *Pleurotus* mushroom's fruiting bodies contained high amounts of vitamin B group such as vegetables. Therefore, in oyster mushroom samples grown on different substrates, niacin and riboflavin were determined (Table 6).

**Table 6. Vitamin contents of dried oyster mushroom cultivated on different substrates**

<table>
<thead>
<tr>
<th>Substrates</th>
<th>Riboflavin</th>
<th>Niacin</th>
</tr>
</thead>
<tbody>
<tr>
<td>W.S</td>
<td>2417.63</td>
<td>27958.3</td>
</tr>
<tr>
<td>R.S</td>
<td>135.38</td>
<td>612.63</td>
</tr>
<tr>
<td>R.S+W.S</td>
<td>116.38</td>
<td>5129.69</td>
</tr>
<tr>
<td>S.D</td>
<td>119.38</td>
<td>1298.34</td>
</tr>
<tr>
<td>S.D+W.S</td>
<td>696.64</td>
<td>143378.5</td>
</tr>
<tr>
<td>W.H</td>
<td>2481.41</td>
<td>1097.45</td>
</tr>
<tr>
<td>W.H+W.S</td>
<td>1596.55</td>
<td>3910.64</td>
</tr>
</tbody>
</table>

Values followed by the same alphabetical letter(s) in common, within a particular group of means in each character, do not significantly differ, using Revised L.S.D test at 0.05 level of probability a,b,c,... Mean values in the same row between different treatments marked with unlike letters are significantly different (p<0.05). Vitamin contents are represented in μg/100 g dry weight.

W.S. mushroom cultivated on wheat straw, R.S. mushroom cultivated on rice straw, R.C+W.S. mushroom cultivated on a mixture of rice straw and wheat straw, S.D .mushroom cultivated on saw dust, S.D+W.S. mushroom cultivated on a mixture of saw dust and wheat straw, W.H. mushroom cultivated on water hyacinth, W .H+W.S. mushroom cultivated on a mixture of water hyacinth and wheat straw.

The results indicated that high amounts of riboflavin were found in the first picking of oyster mushroom grown on water hyacinth (W.H) and wheat straw (W.S) (2481.407 and 2417.63µg/100 g, respectively). While in oyster mushroom grown on combination of rice straw and wheat straw (116.38 µg /100 g), the lowest value was observed. Niacin’s highest values were recorded in oyster mushroom grown in a mixture of saw dust and wheat straw (S.D+W.S), wheat straw (W.S), and rice straw mixture with wheat straw (R+S+W.S) (143378.5, 27958.3, and 5129.69 µg/100 g). Therefore, mushrooms grown on rice (R.S) or wheat (W.S) or mixtures (R.S +W.S) were considered a good source of these vitamins.

**CONCLUSION**

Different substrates have affected *P. ostreatus* nutrient composition in this experiment. The overall nutritional potential of the mushrooms was relatively different from other research findings, despite differences in the chemical composition of *P. ostreatus* grown on different substrates. Since many variables affect the composition of a given species, it is often impossible to compare the results obtained by different researchers working with the same species of mushrooms. However, the present results indicate that significant amounts of valuable fatty acids are contained in economically important wild edible mushrooms. It can also provide economic incentives for agribusiness to look at these residues as valuable resources and develop new businesses to use them to produce nutritious mushroom products. Mushroom cultivation can therefore become one of the most profitable agribusinesses that can produce food products from various substrates and help to dispose of them in an environmentally friendly way. Individual substrate supported mushroom growth, but in nutritional composition the mixed substrate is better than pure substrate. It can be inferred from the study that the combination of rice straw with wheat straw may serve as good substrate for growing better yield as well as quality oyster mushroom. The availability and economy of such substrates is one of the advantages of using them in this study.
The mushroom’s application in dairy products will provide good source of food with high nutrition and prevent some disease, this is a prospect study which will be discussed in the following papers.

CONFLICT OF INTEREST

The authors do not have any conflicts of interest.

ACKNOWLEDGEMENT

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REFERENCES


في محطة البحث الزراعية، الصباحية، الإسكندرية، مصر. أظهرت النتائج أن بيئة (قش الأرز + قش الفحم) المختلفة (R.S) وبيئة قش الأرز بمفردها (R.S + W.S) كان له تأثير كبير على النمو والزيادة في العائد الزراعي.