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Comparison Between Peels of Prickly Pear and Rice Husk as Additives to Rice Straw Substrate for Oyster Mushroom (*Pleurotus columbinus*) Production

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ABSTRACT

The experiment was conducted at Mushroom Research Laboratory Vegetable Crops Department, Faculty of Agriculture Cairo University, Giza and Regional Center for Food and Feed, Agricultural Research Center, Ministry of Agriculture Giza, Egypt during the two successive seasons of 2019/2020 and 2020/2021 under the environmental control of growth chamber. In this study, of oyster mushroom (*Pleurotus columbinus*) was used to evaluate the effect of adding prickly pear peel to the rice straw as the substrate for mushroom production comparing to rice husk additive on growth, yield and quality of mushroom. According to the results rice straw +200 g rice husk can be recommended as additive to rice straw substrate for oyster mushrooms production because it produced the highest cumulative numbers and weight of total and marketable fruits having high quality, represented in high contents of protein%, fiber%, P, Ca, Fe and essential amino acids, while rice straw +100 g rice husk can be recommended for high fruit yield and short harvesting period.

KEYWORDS: Rice straw, Oyster mushroom, Rice husk, Prickly pear peel.

1. INTRODUCTION

Mushroom cultivation is very effective technique to face the problems of food shortage, impairment of human health and environment pollution. These problems are borne, because of the rapid increase in the world population and climate the continuous changes in the climate that resulted in deterioration of natural resources (Chang, 2008)**.** *Pleurotus* mushroom is considered one of the most important cultivated mushrooms all over the world. It comes in the second rank behind *Agaricus* mushroom. Its importance arose from its high adaptation to the different environmental conditions in additions to its great nutritional and health values (Prokisch et al., 2021; Melanouri, et al, 2022). It is a good and cheap source of protein, vitamin, mineral content and various bioactive compounds, beside its low contents of calories, carbohydrates, fat, and sodium. (Jacinto-Azevedo, et al., 2021). Furthermore, mushroom plays a vital role in conventional medicine, where it is used for curing several serious human diseases, including fungal and bacterial infections, diabetes mellitus, , coronary heart disease, immune system disorders, and cancers (Dhamodharan et al., 2010), in addition to Parkinson's, Alzheimer's, hypertension, and stroke (Chugh et al., 2022; Mwangi, et al., 2022)

Pleurotus pulmonarius is the most popular cultivated mushrooms in Egypt and it has become increasingly commercially important. It has a high colonization on different plant residues (Ahmed *et al.,* 2023). Several researches have been carried out to study the growing ability of *Pleurotus spp*. on various agro wastes, which depended on their availability in great amounts and low cost. This condition varies from country to country. These agro-wastes included sawdust, corncob and sugarcane bagasse in Taiwan (Hoa *et al.,* 2018), straw of rice or wheat banana blades, sugarcane biomass, maize ear, and rice husk plus saw dust in Nepal (Dubey *et al.,* 2019) and Bangladesh (Akter *et al.,* 2022), Sawdust, corn cob and rice straw in Philippines (Magolama *et al.,* 2020), rice straw and chopping of Bermuda weeds in Guyana (Adams et al., 2022), saw dust, cotton stalks, wheat straw, maize ear and crushed fruit shells of baobab in Zimbabwe (Zhou and Parawira, 2022), Corn cobs, sugar cane bagasse, cotton waste, sambal tree (*Bombax ceiba* L.) and office scrap paper in Pakistan **(**Zahid et al., 2020; Khan *et al.,* 2021), paper waste, wheat straw, sawdust, rice straw, cottonseed hull, maize cob apple fruits residue, barley straw, sesame stem, cotton seed shell and mixtures of groundnut shell and three vegetable (potato, cabbage and onion) wastes in varying ratios in Ethiopia (Emiru et al., 2016; Tekeste *et al.,* 2020; Bulti 2021), and mixtures of peels of carrot, radish potato or cucumber with sugarcane pomace and rice straw or husk (Shashitha et al., 2016), apple pulpy residue (Pathania *et al*, 2017and straw of rice and wheat, corn ears and sugarcane pomace (Shukla et al., 2020) in India.

In Egypt, all researches used rice straw as a main medium for Oyster Mushroom (*Pleurotus ostreatus*) production. Moreover, several other alternative substrates were used as substitutes for rice straws. These substrates included wheat straw, shoots of cotton, maize, okra legumes and solanaceous (El-Said et al. 2008), clover hay, sugarcane bagasse (Arisha, 2010), sawdust, waste paper and cardboard industrial (Afify *et al*., 2012), wheat straw and sugarcane bagasse (Khalaphallah *et al.,* 2020), alfalfa hay, wheat straw, sawdust, maize ears and soybean shoots (Salama *et al.,* 2016), wheat and legume straw(El-sayed et al., 2019), wheat straw, saw dust and water hyacinth (Elattar *et al.*, 2019) and old mushroom spent substrate (Hamed et al. 2020).

Other researchers added some additives to rice straw to improve the production and quality of Oyster Mushroom, like 15% composted rice straw in mixture with chicken manure and soil, 15% wheat bran, 10% vermicompost+ 5% Azolla extract, which caused increases in yield reached 42.7% (Mohamed et al. 2016), 196.5 %, (Salama et al., 2019), 585.12% (Abou El-Nour and Ibraheim, 2021), respectively. Also, Gomaa et al. (2021) studied the effect of mixing rice straw and wheat grain seed with vermicompost tea, potato dextrose or compost tea and found the mixture of rice straw and vermicompost tea brought 16.4% increase over the control treatment (mixture of rice straw and wheat grain seed).

Prickly pear, *Opuntia ficus-indicaare* is a tropical and subtropical crop that it is cultivated primarily for its fruits. However, the manufacturing of these fruits causes accumulation of various by-products that can be a source of biological and pigmented compounds. Also, their cladodes are used as cattle forage and fodder (Melgar et al., 2017). The previous studies focus mainly on the benefits of the edible fruit, and neglected the benefits of the fruit peels, that have high contents of phenols, flavonoids and dietary fiber. These compounds may be used alternative sources for lipids, carbohydrates and pigments (Manzur-Valdespino *et al*., 2022). To our knowledge, no tried to use the peels of the prickly pear peel as a substrate or additive to the substrate for mushroom production. Therefore, the present investigation was done to study the effect of adding prickly pear peel on the rice straw as the substrate for mushroom production comparing to rice husk additive on productivity and quality of mushroom.

2. MATERIALS AND METHODS

The experiment was conducted at Mushroom Research Laboratory, Vegetable Crops Department, Faculty of Agriculture Cairo University, Giza and Regional Center for Food and Feed, Agricultural Research Center, Ministry of Agriculture Giza, Egypt during the two successive seasons on 25 th of October of 2019 and 2020. In the present work, oyster mushroom (*Pleurotus columbinus*) was used to investigate its growth, yield and quality in rice straw supplied with two different supplementations. The culture of oyster mushroom was obtained from Regional Center for Food and Feed - Agriculture Research Center, Giza. Culture was kept in a refrigerator at 5.8 C as reported by Stamets (1993) until uses with sorghum grains as a spawn medium for producing spawns according to El-Kattan and El-Haddad (1998). The two supplementations rice straw used for this experiment were prickly pear peels and rice husk, each at two levels.

2.1. Substrate preparation

Peels of the prickly pear were collected from the local Giza market. They were washed with water, and then they were dried in oven at 60 C^{o} for 3 days. Then they were ground using a mechanical grinder (Moulinex, Germany).

Rice husk was packed in heat-resistant bags. Thereafter, the bags containing rice husk were autoclaved at 121°C for twenty minutes, according to Zhanxi and Dongmei (2008), and allowed to cool overnight.

Rice straw (*Oryza sativa* L.) was cut to a 5- to 15-cm length with a bale chopper (WIC, Wickham, Quebec, Canada). Twenty-one kilo of rice straw was sterilized for two hours by boiling in lap water.

The substrate (rice straw) was left over night to leach out the excess water before inoculation with spawn. Next day after sterilization, the rice straw was weight to determine the weight of the humid rice straw after sterilization. After that, 45 µm polyethylene bags (40 cm length ×18 cm in diameter) were filled with 3.750 kg humid rice straw media (60 - 75%) then were inoculated under aseptic conditions with 50 g grain spawn (5% rale of spawn) per kg of dry substrate before humid. Calcium sulfate was added to all the treatments at 5% of the substrate dry weight.

The peels of the prickly pear and rice husk were mixed with rice straw at different ratios. Five treatments were established as follows:

1. Rice straw alone (control)
2. Rice straw + 10% prickly pear peels
3. Rice straw + 20% prickly pear peels
4. Rice straw + 100 g rice husk/bag
5. Rice straw + 200 g rice husk/bag

Each treatment consisted of three bags representing three replicates. The treatments were written on the different bags using permanent marker. The bags were arranged randomly on shelves in the growth room.

2.2. Inoculation, incubation, and culture conditions:

The inoculated bags were kept in the culture room in dark at 23 - 25 C until the mushroom mycelium colonized and completely covered all the substrate (21 days later). Then holes were made in the bags to allow formation of fruiting body as reported by Zhang et al. (2002). The proper humidity of bags was achieved by spraying the medium with water twice a day.

2.3. Harvesting and Yield parameters

2.3.1. Harvesting:

Mushrooms were harvested from each bag when the caps became fully mature

2.3.2. Data recorded:

The following measurements were recorded:

A-Fruiting phases and duration:

Earliness: Number of days spent from inoculation until the first harvest of fruit bodies**.**
Harvesting Duration: Number of days between the first picking and last one.

B- Yield parameters:

Average number of clusters/bag:
Total number of fruits /bag: It is calculated by counting the harvested mature fruit bodies in each bag per each flush.
Average number of fruits/cluster: It was estimated by using the formula below: Average number of fruits/cluster= Total number of fruits /bag/ Average number of clusters/bag
Total mushroom yield/bag (g): It was recording by summating weight of all flushes (from the first to the forth flush).
Total weight of marketable yield/bag (g): It was determined by separating all Fruits that are greater than 2cm diameter of each flush (from the first to the forth flush) and weighing, thereafter, the sum of the marketable mushroom yield of all flushes were calculated.

C - Physical characteristics of stipes

Stipe length (cm): The stipe length was measured by using a ruler from substrate surface until base of cap.
Stipe diameter (cm): It was measured by Vernier caliper.

D. Physical and chemical characteristics of fruits

The clusters of the mushrooms were weighed, and following physical and chemical parameters were evaluated

Physical characteristics of fruits
Length and width of cap of fruit body (cm): They were measured by using Vernier caliper.
Average fruit weight (g): it was calculated by division the weight of all harvested fruits in each harvest by the total number of each harvest.

Chemical characteristics
Dried mushroom fruits (in oven at 60°c for 72 hr.) were grinded and used for determined the following major chemical analysis

Mineral contents: Mn, Fe, Ca and P were determined as follows:

The content of calcium, Fe, and manganese were determined by using ICP Spectrometer (ICAP 6000 Series; Thermo Scientific) according to APHA (1999).
Phosphorus was determined colorimetrically according to El- Merzabani et al. (1977).
Total Protein %: Total nitrogen content was at first determined using macro Kjeldhal. according to method described in A.O.A.C. (2012). Thereafter, total protein content of the samples was calculated by multiplying of the percentage content of the total nitrogen by 5.99 (Fujihara etal.,2006).
Total Carbohydrates
Total Carbohydrates were determined calormetrically using the phenol–sulfuric acid method according to Duboies et al. (1956).
Total lipid: Fat content in mushroom fruits was determined by extracting with petroleum ether by using the soxhlet apparatus as described in the A.O.A.C. (2012).
Crude Fiber %: It was determined by digestion method using acid and alkali, according to the method described in A.O.A.C. (2012).
Dry matter
Amino acids: Amino acids fraction was conducted using the method of Block et al. (1958).

2.4. Experimental design and data analysis

The experiment was statistically analyzed in completely randomized design with three replicates (each replicate contain 10 bages) . This experiment included 5 treatments. The obtained data were subjected to the analysis according to the method described by Snedecor and Cochran (1980). Least significant difference (L.S.D) at 0.05 levels was used for comparing observed data.

3. RESULTS

3.1. Effect of different substrates on fruit maturity and harvesting duration

Data presented in Table 1. Show the influence of different substrates on fruit maturity (Days from culture until harvest) and harvesting periods**.** The minimum period required for the first harvest was 45.67 to 47.33 days, that was

Table 1. Effect of different substrates on maturity and clusters yield of oyster mushroom during 2019/ 2020 and 2020/2021 seasons

Characteristics	Days from culture until harvest		Harvest duration (days)		Clusters No. /Bag	
Substrates	**1st Season**	**2nd Season**	**1st Season**	**2nd Season**	**1st Season**	**2nd Season**
Rice straw	47.33 b	45.67 b	60.83 a	59.67 b	5.50 cd	6.00 b
Rice straw +10% prickly pear peels	57.00 b	59.50 b	71.33 a	76.67 a	7.50 b	8.50 a
Rice straw +20% prickly pear peels	56.17 b	59.83 b	62.5 a	70.5 a	5.33 d	5.67 b
Rice straw +100 g rice husk	132.00 a	140.25 a	46.67 b	46.33 c	6.50 bc	6.50 b
Rice straw +200 g rice husk	117.67 a	125.83 a	44 b	41.5 c	8.67 a	8.33 a

Characteristics	Fruits weight /Cluster (g)		Fruits No. /Cluster	
Substrates	**1st Season**	**2nd Season**	**1st Season**	**2nd Season**
Rice straw	53.47c	49.95 cd	5.97 c	5.83 b
Rice straw +10% prickly pear peels	54.17 c	46.77 d	6.86 b	6.81 b
Rice straw +20% prickly pear peels	61.21 c	59.81 c	6.35 bc	6.75 b
Rice straw +100 g rice husk	71.7 b	79.89 b	10.00 a	10.00 a
Rice straw +200 g rice husk	90.36 a	107 a	6.58 bc	6.23 b

obtained in rice straw alone (control treatment), followed by 56.17 to 59.83 days then 57.00 to 59.50 days in straw+20% prickly peels and straw+10% prickly peels, respectively, while first harvest of straw + rice husk was achieved very late to be117.67 - 125.83 days and 132.00-140.00 days.

Different substrates significantly affected harvest duration of mushroom. Prickly pear peels substrates extended the harvest duration, while adding rice husk to rice straw significantly shortened the harvest duration, as compared with the control (rice straw alone)

3.2.Effect of different substrates on yield of oyster mushroom and its components

3.2.1. Effect on clusters yield

Data in Table 1 reveal that clusters yield, i.e., number of cluster/bags, weight of fruit/cluster and number of fruits/cluster, significantly influenced by the different substrates. As compared with using rice straw alone, there were significant increases in average number of clusters/bag due to using rice straw +10% prickly pear peels in the first season and rice straw +200 g rice husk in both seasons, average fruits weight of cluster (g) by using rice straw +100 g rice husk and rice straw +200 g rice husk in both seasons, and average number of fruits/cluster due to using rice straw +10% prickly pear peels and rice straw +100 g rice husk in the first season and the two seasons, respectively. Moreover, rice straw +200 g rice husk produced the highest value of average cluster weight (g) and clusters number/bag, while rice straw +100 g rice husk produced the highest value of average number of fruits/cluster.

3.2.2. Effect on mushroom yield / bag

Data in Table 2 present that cumulative total number of fruits/bags produced on substrates of rice straw +100 or 200 g rice husk and rice straw +10% prickly pear peels were significantly higher as compared with using rice straw alone. Rice straw +100 g rice husk had the highest cumulative number of fruits produced

Table 2. Effect of different substrates on bag yield of oyster mushroom during 2019/ 2020 and 2020/2021 seasons.

Characteristics	Total number of fruits /Bags		Total weight of fruits /Bag(g)		Marketable weight of fruits /Bag (g)	
Substrates	**1st Season**	**2nd Season**	**1st Season**	**2nd Season**	**1st Season**	**2nd Season**
Rice straw	32.68 c	34.77 c	307.6 c	300.5 c	166.6 c	190.7 c
Rice straw +10% prickly pear peels	50.09 b	58.32 ab	390.2 c	387.1 c	241.5 c	232.7 c
Rice straw +20% prickly pear peels	33.62 c	38.91 c	393.3 c	384.2 c	219.7 c	231.4 c
Rice straw +100 g rice husk	65.00 a	64.33 a	647.6 b	678.5 b	587.6 b	539.7 b
Rice straw +200 g rice husk	57.29 ab	51.3 b	1266 a	1221 a	730.9 a	847.5 a

Table 3. Effect of different substrates on different fruit yield flushes of oyster mushroom during 2019/ 2020 and 2020/2021 seasons.

Characteristics	First flush		Second flush		Third flush		Fourth flush	
Substrates	**1st Season**	**2nd Season**	**1st Season**	**2nd Season**	**1st Season**	**2nd Season**	**1st Season**	**2nd Season**
Rice straw	107.9c	152.7b	102.4c	86.43b	62.93d	44.22d	34.33c	17.17d
Rice straw +10% prickly pear peels	186.4 b	152.2 b	72.47 d	95.23 b	81c	89.5 c	50.35c	50.21c
Rice straw +20% prickly pear peels	87.96c	80.23 b	112.5 b	111 b	85.5c	99c	107.3 b	94b
Rice straw +100 g rice husk	416.6a	445.5 a	76d	91b	155b	142b	0d	0e
Rice straw +200 g rice husk	452 a	505.5 a	388.7a	353.6a	269.6a	228a	155.3 a	133.8a

(65 and 64.33, in the first and second season, respectively) followed by straw+200 g rice husk (57.29) then rice straw +10% prickly pear peels (50.09) in the first season, and rice straw +10% prickly pear peels (58.32) then rice straw +200 g rice husk (51.3), in the second season. Both treatments of rice husk, i.e., rice straw +100 g rice husk and rice straw +200 g rice husk, significantly increased total fresh fruit yield of mushroom bodies as compared with rice straw alone. Furthermore, rice straw +200 g rice husk (1266 and 1221 g) followed by rice straw +100 g rice husk (647.6 and 678.5 g) produced the highest cumulative fresh fruit yield of oyster mushrooms per bag in the first and second season, respectively. Meanwhile, no significant differences in the total fresh weight of mushroom fruits were detected between prickly pear peels treatments (rice straw +10% prickly pear peels and rice straw +20% prickly pear peels) and the control treatment (rice straw alone).

Marketable weight of fruits / bag (g) took the same trend of effect of different substrates on cumulative fresh fruit yield, where the highest marketable yield was recorded by using rice straw +200 g rice husk followed by rice straw +100 g rice husk in the first and second season, respectively. Also, no remarkable differences in the marketable yield of mushroom fruits were detected between Prickly pear Peels treatments (rice straw +10% prickly pear peels and rice straw +20% Prickly pear peels) and the control treatment (rice straw alone).

3.2.3. Effect on fruit yield of different flushes of oyster mushroom/ bag

Generally, first flash gave the highest mean yield whereas the fourth flush showed the lowest mean yield.

Total weight of mushroom fruits per bag in the first flash ranged from 87.96 g to 452.00 g and 80.23 g to 505.5 g, in the first and second season, respectively. Comparing with rice straw alone (control), rice straw+100 g rice husk and rice straw+200 g rice husk increased yield of first flush, while rice straw+20% prickly pear peels decrease it. Rice straw+200 g rice husk gave the highest fruit yield, while rice straw+20% prickly pear peels gave the lowest one.

In the second flush, total weight of fruiting bodies per bag was generally decreased and ranged from 72.47 g to 388.67 g and 86.43 g to 353.55 g, in the first and second season, respectively. Rice straw+200 g rice husk and rice straw+20% prickly pear peels increased yield; however, rice straw+200 g rice husk showed significantly the highest value. In contrast, rice straw+10% prickly pear peels and rice straw+100 g rice husk showed lower yield in the first season than recorded on rice straw alone.

In the third flush, total weight of fruiting bodies per bag was further decreased and ranged from 62.93 g to 269.64 g and 44.22 g to 228 g/bag, in the first and second season, respectively. All treatments gave significantly higher yield than the control treatment; i.e., rice straw alone, which produced 62.93g and 44.22 g / bag only, in the first and second season, respectively. Furthermore, rice straw+200 g RH showed significantly the highest yield (269.64 g g and 228 g/bag, in the first and second season, respectively), and followed by rice straw+100 g RH (155.0g and 142.00 g/bag, in the first and second season, respectively) in this respect.

Table 4. Effect of different substrates on physical characteristics of oyster mushroom during 2019/ 2020 and 2020/2021 seasons.

Characteristics	Average fruit weight (g)		Fruit length (cm)		Fruit width (cm)	
Substrates	**1st Season**	**2nd Season**	**1st Season**	**2nd Season**	**1st Season**	**2nd Season**
Rice straw	15.86 b	13.61 b	7.75c	7.70 c	6.49b	6.71b
Rice straw +10% prickly pear peels	16.5b	16.59b	8.10 bc	7.69 c	6.85 b	6.54 b
Rice straw +20% prickly pear peels	18.2b	17.72b	8.45 abc	8.16 bc	6.56 b	6.52 b
Rice straw +100 g rice husk	24.72a	23.23a	8.91ab	8.98 ab	7.91 a	7.99 a
Rice straw +200 g rice husk	25.59a	26.48a	9.22 a	9.36 a	7.90 a	7.83 a

Characteristics	Stipe length (cm)		Stipe diameter (cm)	
Substrates	**1st Season**	**2nd Season**	**1st Season**	**2nd Season**
Rice straw	2.10 C	2.11 c	1.25b	1.36b
Rice straw +10% prickly pear peels	2.84 c	2.90 c	1.47ab	1.31 b
Rice straw +20% prickly pear peels	2.71 c	2.92 c	1.35ab	1.24 b
Rice straw +100 g rice husk	7.42a	7.39 a	1.42ab	1.42 b
Rice straw +200 g rice husk	5.53 b	5.70 b	1.66a	1.76a

In the fourth flush, total weight of fruiting bodies per bag was lowest and ranged from 0 g to 155.3 g and 0 g to 133.8g/bag, in the first and second season, respectively. The treatment of rice straw+100 g rice husk stopped producing fruits in this flush. On the other hand, other treatments caused significantly greater fruit yield. The yield of the treatment of rice straw+200 g RH (155.3

and 133.8 g/bag) followed by the treatment of rice straw+20% prickly pear peels (107 and 94 g/bag) were superior in the first and second season, respectively in this concern. The yield of rice straw alone (control) in this flush was 34.33 and 17.17 g/bag, in the first and second season, respectively.

3.2.4. Effect on physical characteristics of fruits

It is obvious from the present results that, the maximum values of fruit length were obtained when mushroom cultured on rice straw medium + 200 g rice husk (9.22 and 9.36 cm) followed by using rice straw substrate plus 100 g rice husk (8.91 and 8.98 cm) in the first and second season, respectively. Data also reveal that the maximum fruit width was obtained on rice straw substrate plus 100 g rice husk (7.91 and 7.99 cm) and followed by using rice straw substrate plus 200 g rice husk (7.90 and 7.83 cm) in the first and second season, respectively, with no remarkable differences between both treatments. Conversely, the minimum fruit length of fruit bodies was produced on the substrate of rice straw alone in both seasons of study, while the fruit width of fruit bodies was produced on rice straw alone medium (6.49 cm) and rice straw +20% Prickly pear peels (6.52 cm) in the first season and in both seasons, respectively.

Concerning average fruit weight, data of the same Table indicated that the greatest average fruit weight was registered on rice straw substrate plus 200 g rice husk (25.59 and26.48 g) in the first and second season, respectively, followed by using rice straw substrate + 100 g rice husk (24.72 and 23.23 g) in both seasons, respectively, with no remarkable differences between the two treatments. In contrast, the lowest average fruit weight, was recorded on medium containing rice straw alone (15.86 and 13.61g) followed by rice straw plus 10% prickly pear peels (16.5 and 16.59 g) then rice straw plus 10% prickly pear peels (18.2 and 17.72 g) in both seasons, respectively, with no remarkable differences among treatments .

Regarding stipe characters, data clearly indicated that, the highest value of stipe length was noticed when oyster mushroom was cultured on rice straw substrate plus 100 g rice husk (7.42 and 7.39 cm) followed by culturing on rice straw substrate plus 200 g rice husk (5.53 and 5.70 cm) in the first and second season, respectively, with significant differences comparing with using rice straw alone that showed the lowest value recording 2.10 and 2.11 cm, in both seasons, respectively. Additionally, the highest stipe diameter was observed when oyster mushroom was grown on rice straw substrate plus 200 g rice husk (1.66 and 1.76 cm) in the first and second season, respectively, while the lowest stipe diameter was recorded when mushroom was grown on rice straw alone in the first season (1.25 cm) and on rice straw +20% prickly pear peel peels (1.24 cm) in the second season.

3.3. Effect of different substrates on chemical composition of oyster mushroom fruits

3.3.1. Effect on mineral composition of oyster mushroom fruits

Supplementing rice straw with prickly pear peels or rice husk significantly improved mineral contents of mushroom as compared to using rice straw alone. Straw+200 g rice husk had a significantly the highest content of P, Ca and Fe in both seasons.

Straw+100 g rice husk came at the second rank regarding P, Ca and Fe in both seasons. So, Ca and P were significantly increased at 200 and 100 g supplementation of rice husk. Rice straw+10 or 20 % prickly pear peels revealed the third lank regarding fruit contents of P and Ca with significant differences as compared with rice straw alone, except in the case of P in the first season. Furthermore, adding prickly pear peels at 20% followed 10% to rice straw resulted in producing the highest amount of Mn in mushroom fruits.

Table 5. Effect of different substrates on mineral contents of oyster mushroom during 2019/ 2020 and 2020/2021 seasons

Characteristics	P (mg/kg)		Ca (mg/ kg)		Mn (mg/kg)		Fe (mg/kg)	
Substrates	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Rice straw	3461.93b	3300.33d	92.01d	92.2d	15.11d	18.27e	115.9d	120.6c
Rice straw +10% prickly pear peels	3744.53 b	4050.60 c	116 c	140.1 c	117.8a	122.5 b	138.8cd	144c
Rice straw +20% prickly pear peels	4036.03b	4100.60 c	150.2b	175.4ab	126.8a	140.3 a	153.6c	155.1c
Rice straw+100 g rice husk	4478.93b	5420.67 b	168.8ab	170b	50.28 c	52.93d	300.5b	323.3b
Rice straw +200 g rice husk	5938.20a	6656.00 a	190.4a	192a	61.53b	70.37 C	376a	427.7a

	P (mg/kg)	Ca (mg/ kg)	Mn (mg/kg)	Fe (mg/kg)
Prickly pear peels	483.2	2.7	110.06	50.9
Rice husk	2983.6	668.6	53.8	483.4

Table 6. Effect of different substrates on protein, fat and fiber of oyster mushroom during 2019/ 2020 and 2020/2021 seasons

Characteristics	Dry matter (%)		Fiber%		Protein%		Fat %	
Substrates	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Rice straw	18.12 b	16.78 b	14.85 c	13.62 c	6.64 c	7.06 c	1.47 a	1.45 c
Rice straw +10% prickly pear peels	23.82 ab	22.81 ab	16.5 bc	15.94 bc	16.20 b	14.33 b	1.92 a	2.15 ab
Rice straw +20% prickly pear peels	24.83 ab	23.56 a	19.22 b	19.55 b	18.02 ab	19.46 a	2.02 a	2.39 a
Rice straw +100 g rice husk	25.77 a	24.39 a	20.02 b	19.72 b	20.19 a	20.63a	1.69 a	1.72 bc
Rice straw +200 g rice husk	26.63 a	25.51 a	24.23 a	25.6 a	21.11 a	19.81 a	1.91 a	2.17 ab

	Fiber%	Protein%	Fat %
Prickly pear peels	12.29	5.1	2.5
Rice husk	24.61	7.2	2.22

3.3.2. Effect on proximate content of oyster mushroom fruits

All supplementations caused a significant increase in dry matter, fiber, protein and fat of oyster mushroom. Straw+200 g rice husk followed by straw+100 g rice husk were the superior treatments in this respect (Table 6). The protein contents in mushroom fruits produced on a medium containing rice husk ranged from 19.81 to 21.11 %, and on the medium of straw+20% prickly pear peels from 18.02 to 19.46 %, while it ranged from 6.64 to 7.06% in rice straw alone.

Table 7. Effect of different substrates on amino acids contents of oyster mushroom during 2019/ 2020 and 2020/2021 seasons

	Straw control	Straw+ 10% prickly pear peels	Straw+20 % prickly pear peels	Straw+ 100 g rice husk	Straw+ 200 g rice husk	Straw control	Straw+ 10% prickly pear peels	Straw+ 20 % prickly pear peels	Straw+ 100 g rice husk	Straw+ 200 g rice husk
			1st Season					2nd Season		
Aspartic (ASP)	1.25 e	1.62 b	1.67a	1.40 d	1.58 c	1.24 e	1.62 b	1.66 a	1.40 d	1.58 c
Therionine(THR)	0.61 d	0.78 ab	0.81 a	0.71c	0.77 b	0.64 d	0.79 ab	0.79 a	0.71 c	0.77 b
Serine(SER)	0.60 d	0.72 b	0.76 a	0.69 c	0.76a	0.61c	0.73 a	0.76 a	0.69 b	0.76 a
Glutamic (GLU)	2.28e	2.96d	4.02 a	3.14 c	3.41 b	2.28 e	2.94 d	4.06 a	3.13 c	3.40 b
Glycine(GLY)	0.60 d	0.77 b	0.82a	0.69c	0.77 b	0.61 d	0.77 b	0.82 a	0.69 c	0.76 b
Alanine (ALA)	0.77 d	1.01 b	1.10 a	0.88 c	1.01 b	0.77 d	1.00 b	1.10 a	0.89 c	0.99 b
Valine (VAL)	0.60 d	0.77 a	0.77 a	0.67 c	0.72 b	0.60 d	0.77 a	0.77 a	0.68 c	0.72 b
Proline(PRO)	0.53 c	0.70 b	0.70 b	1.62 a	0.68 b	0.54 a	0.69 a	0.69 a	0.96 a	0.67 a
Cystine(CYS)	0.15 c	0.19 b	0.22 a	0.18 b	0.21 a	0.16 c	0.20 ab	0.21 a	0.18 b	0.20 a
Isoleucine(ILE)	0.53 d	0.66 b	0.67 ab	0.61 c	0.7 a	0.51 d	0.67 b	0.67 b	0.61 c	0.7 a
leucine(LEU)	0.91 b	1.12 a	1.16 a	1.13 a	1.09 a	0.92 b	1.14 a	1.14 a	1.1 a	1.09 a
Tyrosine (TYR)	0.25 c	0.41 b	0.48 a	0.48 a	0.49a	0.25 c	0.40 b	0.48 a	0.48 a	0.47 a
Phenylalanine(PHE)	1.55 e	1.72 d	1.86 b	1.82 c	1.91a	1.54 e	1.72 d	1.85 b	1.82 c	1.91 a
Histidine (HIS)	0.3 b	0.36 ab	0.41 a	0.37 ab	0.41 a	0.4 a	0.37 a	0.42 a	0.36 a	0.41 a
Lysine (LYS)	0.77 e	0.87 d	0.98 b	0.94 c	1.07 a	0.78 e	0.87 d	0.97 b	0.94 c	1.07 a
Methionine	0.24 c	0.3 ab	0.29 ab	0.29 b	0.32 a	0.24 c	0.31 ab	0.28 b	0.3 ab	0.32 a
Argnine (ARG)	0.71 d	0.97 a	0.93 ab	0.77 c	0.89b	0.70 c	1.00 a	0.93 ab	0.77 c	0.88 b

Fat content ranged from 1.45 % in fruits of the rice straw medium to 2.39% in the medium of sraw+20% prickly pear peels, with significant differences between them in the second trial. Furthermore, fiber content ranged from 13.62% in fruits of the rice straw medium to 25.6 % in the medium of rice straw +200 g rice husk, with remarkable differences between the two treatments.

3.3.3. Effect on amino acids

All media additives improved the mushroom fruit content of amino acids.

Mushroom produced on medium containing 20% prickly pear peels had the highest contents of aspartic, therionine, glutamic, glycine, alanine, valine and leucine. Additionally, the greatest values of isoleucine, phenylalanine, lysine and methionine were detected, when the production was conducted on straw+200 g husk rice. Arginine showed the highest value in fruits obtained from the medium of straw+10% prickly pear peels.

Fruits obtained from the medium of 20% prickly pear peels and straw+200 g husk rice contents higher values of serine, cystine, tyrosine and histidine than other media with no remarkable differences between the two superior media in this respect

4. DISCUSSION

The main nutrient requires for the growth of oster mushroom is carbon source, such as cellulose, hemicellulose and lignin. However, Oster Mushroom also needs nitrogen and inorganic compounds to achieve the maximum growth. The substrate materials used alone for oster mushroom production, such as the straw of rice, sometimes are poor in nitrogen and the other nutrients needed for the optimal production(Siqueira et al. 2012; Soliman 2011). Therefore, some supplements are required to supply the medium culture with nitrogen (Soliman 2011; Jafarpour and Eghbalsaeed 2012).In the present study, we compared between two additives, namely, rice husk and prickly pear peels, as nitrogen and other nutrients on the oster mushroom production and quality.

4.1.Effect of different substrates on fruit maturity and harvesting duration

Adding 200 g rice husk to rice straw delayed the first harvest from47.33- 45.67days in the rice straw alone (control) to 117.67-125.83 days in 200 g rice husk + rice straw. The delay in the harvest may be due to existence of some growth retardants in rice husk. The results of Abou El-Nour and Ibraheim (2021) indicated that mushroom fruits required from spawn culture to be harvested from 33.19 to 32-56 day. On the other hand, Bughio (2001) reported that period required from spawn culture to fruit harvesting ranged from 30 to 56 days. The variation in the different results may be attributed to the composition of culture medium. In this regard, Narain et al. (2008) attributed the early fruit harvest to the substrate contents of required nutrients which push mushroom to grow and develop.

According to the results of Rosdiana and Baharuddin (2020) oyster mushroom needed from the inoculation until first harvest,about 67 days on a substrate consisted of 100% sago pulp, but only 42 days in a substrate consisted of 50% sago pulp + 50% rice husk.

Harvest duration of mushroom fruits significantly varied among different treatments. While the culture substrates containing prickly pear peels extended the harvest duration, adding rice husk to rice straw significantly shortened the harvest duration, comparing with the control (rice straw alone). The harvest duration from 39.00 – 41.00 day in rice husk medium, to 58.50- 62.00 day in rice straw medium (control treatment) and 74.50 – 82.00 day in prickly pear peels medium. Abou El-Nour and Ibraheim (2021) found that the harvest duration for mushroom (*Pleurotus columbines*) grown on rice straw medium ranged from 23.91 to 24.12 day, while it ranged from 14.20 to 18.70 day on a medium consisting of rice straw plus vermicompost at (10%).

4.2.Effect of different substrates on yield of oyster mushroom and its components

Rice straw +200 g rice husk followed by rice straw +100 g rice husk showed the highest value of cumulative fruit yield of mushrooms per bag, with significant differences comparing to all other substrates, including using rice straw alone (control). Rice straw +200 g rice husk showed also the highest significant values of average number of clusters/bag, marketable weight of fruits / bag, fruit yield of each flush, average fruit weight, and fruit length. These results indicated that the highest cumulative fresh fruit yield of oyster mushrooms per bag was related to obtaining the highest number of clusters/bags and the greatest physical fruit characters, namely, average fruit weight and fruit length. Meanwhile, obtaining the highest average fruit weight led to getting the highest marketable fruits weight and highest fruits weight at each flush. On the other hand, the substrate consisted of rice straw +100 g rice husk came at the second rank concerning the cumulative fresh fruit yield of oyster mushrooms per bag. These results were connected with producing of the highest number of fruits/cluster and fruits with high average fruit weight and highest average fruit width, that led to achieve the second rank of marketable yield and yield of the first, second and third fluch/bag. Generally, the variation in the yield of various substrates may be related to the chemical composition of substrate. The present results agree with the outcomes of Patil et al. (2010) who revealed that mushroom production is related with the nutritional composition of culture medium. The high mushroom yield might be resulted from the high available nutrient contents that might provide mushroom mycelium with energy that encouraged growth and led to greater fruit formation. The chemical analysis of rice husk proved that it is rich in protein (7.2**%)** and mineral elements (2983.6 mg/ kg P, 668.6 mg/ kg Ca and 483.4 mg/ kg Fe). On the other hand, it was reported that the main components of rice straw are lignin, cellulose and hemicelluloses, that are considered the carbon sources in the substrate. However, rice straw have a very low concentration of nitrogen. Furthermore, nitrogen in rice straw became available only after it is released through enzymatic prosses during growth of mushroom **(**Lin, 2000). Nitrogen is the element responsible for the synthesis of enzymes and protein, which causes the decomposition of the straw that leads to growth and mushroom fruit formation (Abdul-Qader *et al.,* 2019). The lower content of microelements (N, P. Ca) in rice straw resulted in producing lower numbers of flushes and caps and consequently, lower fresh yield of oyster mushroom fruits. The chemical analysis of the rice straw indicated that it composites of 71% Holocellulose , 12.3% Lignin, 14.17 Soluble materials and 2.3 Pectin (Shoaib et al., 2018). On the other hand, the superiority of rice husk in increasing the fruit yield of mushroom fruits may be attributed the high levels of N, P, Ca and Fe in rice husk, which led to producing a high number of fruits and improvement in average fruit weight. It was reported that button mushroom (*Agaricus bisporus*) needs relatively high nitrogen source, therefore the best C/N ratio of button mushroom compost is 17, while oyster mushroom require less nitrogen and more carbon source (Haas and James, 2009).

These findings are consistent with that of Sofi et al. (2014), who reported that wood fragments mixed with wheat straw achieved a higher yield than single use of waste paper and wheat straw medium.

Rice straw+10% Prickly pear peels significantly increased clusters number /bag, total fruit snumber / bags, in first and third flush in the first trial, while rice straw+20% prickly pear peels significantly increased second, third and fourth flush. Moreover, both these treatments caused a relative improvement in marketable fruits weight / bag and total fruits weight / bag, comparing with using straw alone. The present results may be attributed to the chemical composition of prickly pear peels that contains 5.1% protein, 483.2 mg/kg P,110.06 mg/kg Mn and 50.9 mg/kg Fe.

Generally, first flash gave the highest mean yield whereas the fourth flush showed the lowest mean yield. These results were noticed whatever used substrate. (Table 3). These results are in agreements of Frimpong–Manso et al. (2011) who indicated that the amount of available nitrogen in a substrate reduced with the progress of harvesting, which leads to a lower yield in the last flush comparing to the first one.

Moreover, obtaining 4 flushes in the present study from all substrates, except rice straw+100 g rice husk, are in harmony with those found by Frimpong–Manso et al. (2011), but are not inconsistent with the findings of Sharma et al.

(2013), who harvested only two flushes of mushrooms in their study.

In this study, the maximum stiple diameter and length of oyster mushroom was found on rice straw+ rice husk medium. Mondal et al. (2010) reported that Oyster mushroom quality corresponding with stiple diameter and length. The longer the stiple, the lowermushroom quality. Therefore, mushroom producers should use substrates that promote production of short stiple to have high quality of marketable yield.

4.3.Effect of different substrates on chemical composition of oyster mushroom fruits

Prickly pear peels and rice husk, as additives for rice straw substrate, are different in their contents of minerals, where P, Ca, Mn and Fe contents in prickly pear peels were 483.2, 2.7, 110.06 and 50.9,, and mg/kg, respectively, while they were2983.6, 668.6, 53.8 and 483.4 mg/kg, respectively, in rice husk. This indicates that rice husk is very rich in P, Ca and Fe, while prickly pear peels rich in Mn.

Supplementing rice straw with prickly pear peels or rice husk significantly improved mineral contents of mushroom as compared to using rice straw alone. Straw+200 g rice husk followed by Straw+100 g rice husk had a significantly the highest content of P, Ca and Fe. According to Frimpong–Manso et al. (2011) fruit body of Oster mushroom cultured on the substrate of rice bran plus 2% rice husk contained Ca, P and Fe at a concentration of 1567, 1447 and 15.0 mg/100g, respectively, comparing with 43.1, 939 and 42.6 mg/100g, respectively in fruit body of *P. ostreatus* cultured on the substrate of rice bran alone. The superiority of rice husk in increasing the contents of P, Ca and Fe in mushroom fruits may be attributed the high concentrations of these elements in rice husk.

Furthermore, rice straw+10 or 20 % prickly pear peels showed significantly higher contents of P (mg/ kg) and Ca (mg/kg) as compared with rice alone, except in the case of Ca in the first season. The chemical analysis of Prickly pear peels revealed that it contains 2.7mg/kg Ca and 483.2 mg/kg P. These elements may be translocated from the substrate to mushroom fruits resulting increasing for these elements in them.

Concerning Mn levels, straw+20% prickly pear peels followed by straw+10% prickly pear peels contained the highest amount of Mn. The chemical analysis of prickly peel peels revealed existence of the highest concentration of Mn that cause existence of Mn in mushroom fruits over other media. Our findings are in accordance with the outcomes of Gupta et al. (2013) and King et al. (2016) who indicated that the chemical composition of mushroom fruits depend on the nutritional contents of growth medium.

All supplementations caused a significant increase in the chemical contents (i.e., dry matter, fiber, protein and fat) of mushroom fruits. Straw+200 g rice husk followed by straw+100 g rice husk were the superior treatments in this concern (Table 6). Similarly, Iruoma and Nduka (2012) found that Casing of cassava peel with rice husk markedly increased the protein, fiber and ash contents of mushroom fruits as compared to using cassava peel alone.

Depend on the used substrate, the protein contents in mushroom fruits produced ranged from 7.37% to 22.03%, while fat content ranged from 1.45 % to 2.39%. On the other hand, fiber content ranged from 13.62% to 26.1 %. These results in agreements of the results of Iruoma and Nduka (2012), Gupta et al. (2013) and King et al. (2016), who indicated that the chemical composition of mushroom fruits depend on the nutritional contents of growth medium. On the other hand, Frimpong–Manso et al. (2011) recorded increase in fat, ash, total carbohydrate and decrease in Crude protein in mushroom grown on substrate consisted of rice bran and 2% rice husk comparing with the substrate of Rice bran alone.

All substrate additives improved the mushroom fruit content of amino acids. The human body cannot produce the essential amino acids that include, Histidine, Isoleucine, leucine, lysine, Methionine, Phenylalanine, Threonine, Tryptophan, and arginine. Non-essential amino acids can be made by humans and so are essential to the human diet. They included asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, serine, and tyrosine (Campbell., 2022).

Mushroom produced on substrate containing 20% prickly pear peels had the highest contents of aspartic, therionine, glutamic, glycine, alanine, valine and leucine. Arginine showed the highest value in fruits obtained from the substrate of straw+10% prickly pear peels. Oliveira et al. (2001) reported that Prickly pear peel is rich in the essential amino acids, such as Aspartic acid (1.27%), threonine (0.97%), glutamic acid (0.88%), valine (0.70%), arginine (0.82%), and phenylalanine (0.51%). This analysis might explain the high contents of mushroom fruits grown on substrate supplemented with prickly pear peels. Arginine is very important amino acid, for quick development (e.g., in childbearing and adolescence), strength body exercise, trauma, recovery from lifelong diseases and surgery (Ścibior and Czeczot, 2004). Isoleucine, leucine and valine are essential amino acids because of its vital roles in modulating blood sugar levels, hemoglobin synthesis and the response of the body to hard conditions (Campbell, 2022).Glutamic acid is very important as it acts as antitumor promotor (Dutta et al., 2013). Aspartic acid is suggested to be involved in the regulation of hormone biosynthesis (Usiello et al., 2020),

From other side, the greatest values of isoleucine, phenylalanine, lysine and methionine, were detected in mushroom cultured on straw+200 g husk rice. Phenylalanine is an essential amino acid that is converted in liver to tyrosine, both have a vital role in metabolism of hormones and adrenaline. (Campbell, 2022).

Fruits obtained from the substrate of 20% prickly pear peels and straw+200 g husk rice contents higher values of serine, cystine, tyrosine and histidine than other substrates with no remarkable differences between the two superior substrates in this respect. It was reported that prickly pear peel contains 0.68% serine (Oliveira et al., 2001).

5. CONCLUSIONS

According to the results rice straw +200 g rice Husk can be recommended as additive to rice straw substrate for oyster mushrooms production because it produced the highest cumulative numbers and weight of total and marketable fruits having high quality, represented in high contents of protein%, fiber%, P, Ca< Fe and essential amino acids, while rice straw +100 g rice Husk can be recommended for high fruit yield and short harvesting period.

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الملخص العربي

مقارنة بين قشر التين الشوكي وقشر الأرز كإضافات لبيئة قش الأرز لإنتاج عيش الغراب المحارى (*Pleurotus columbinus*)

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اجريت التجربة في معمل أبحاث عيش الغراب ، قسم الخضر ، كلية الزراعة جامعة القاهرة ، الجيزة والمركز الإقليمي للأغذية والأعلاف ، مركز البحوث الزراعية بوزارة الزراعة بالجيزة ، خلال الموسمين المتتاليين ٢٠٢٠/٢٠١٩ و ٢٠٢١/٢٠٢٠. فى ظروف بيئة متحكم فيها لغرفة النمو. في هذه الدراسة ، تم استخدام عيش الغراب المحارى (*Pleurotus columbinus*) لتقييم تأثير إضافة قشر التين الشوكي إلى قش الأرز كبيئة لإنتاج عيش الغراب مقارنة بإضافة قشر الأرز على نمو وإنتاجية وجودة العيش الغراب. وفقًا للنتائج ، يمكن التوصية بقش الأرز + ٢٠٠ جرام من قشر الأرز كمادة مضافة إلى بيئة قش الأرز لإنتاج عيش الغراب المحارى لأنها أنتجت أعلى عدد ووزن من الثمارالكلية والقابلة للتسويق بجودة عالية ، ممثلة بمحتويات عالية من البروتين ، الألياف ، الفوسفور و الكالسيوم و الحديد و الأحماض الأمنية الأساسية ، بينما يمكن التوصية بقش الأرز +١٠٠ جم من قشور الأرز لزيادة الإنتاجية من الثمار وتقصر فترة الحصاد.

الكلمات المفتاحية: قش الأرز ، عيش الغراب المحارى ، قشر الأرز ، قشر التين الشوكي