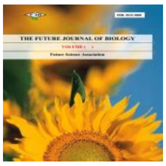

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Evaluate the Effect of Different Types of Damaged Paper in Production of Oyster Mushroom

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Abstract: This research was conducted at the Agricultural Technical College/Northern Technical University during the period April 2025. The aim was to evaluate the effect of different types of damaged paper on the production of *Pleurotus ostreatus*. The damaged papers were collected from the offices of the Northern Technical University and divided into three treatments (printing A4 paper 100%, cardboard paper 100% and Mixed papers of printing A4 paper 50% and cardboard paper 50%). The results showed that the paper Mixed papers treatment gave the highest mushroom productivity with a value of 500 g/kg paper at a significant level of 5% compared to the other treatments, followed by the cardboard treatment of 430 g/kg paper and then the paper A4 treatment, which gave 380 g/kg paper. The highest biological efficiency was recorded in the paper Mixed papers treatment (79%), followed cardboard (74%) and paper A4 (70%). Thus, the study indicated that waste paper would be the most suitable substrate for oyster mushroom cultivation. This research somewhat highlights the option of using waste paper in a sustainable mushroom cultivation practice, contributing to environmental sustainability and food security.

Key words: Oyster mushroom, Paper, cardboard, productivity, Biological Efficiency.

1. Introduction

Fungi are heterotrophic organisms, obtaining nutrients from organic sources by decomposing dead organisms and tissues and using them as foodstuffs (Puzanskiy *et al.*,2024). The mushroom *Pleurotus ostreatus* belongs to the kingdom Fungi, phylum Basidiomycota. Pleurotus spp. are found in most countries, especially in Iraq **(El-Ramady, 2022)**.

The oyster mushroom *P. ostreatus* was successfully cultivated at the beginning of the nineteenth century, and the importance of its cultivation increased due to its ease of cultivation, its high nutritional and medical value, its unique flavor and antimicrobial activity, and its effective role in purifying the environment polluted by industrial waste, heavy metals and crude oil, as *P. ostreatus* is one of the most commercially available fungi, successfully cultivated, and considered a delicacy after *Agaricus bisporus* and *Lentinus edodes* **(Raman *et al.*, 2020 and Tiupova *et al.*, 2025)**.

Several studies have been conducted in Iraq on the cultivation of Pleurotus spp. Oyster mushrooms have been produced using different agricultural residues, such as rice straw, wheat, barley, paper and cardboard **(Aditya *et al*., 2024 and Ritota *et al*., 2019)**. Oyster mushroom cultivation is a vital process for recycling lignocellulosic waste and can be produced at the family level at home, representing an opportunity to increase the national income of the country **(Dey *et al*., 2024 and Padam *et al*., 2012)**.

Damaged paper and cardboard are both wastes and industrial wastes that may impact the environment and are rich in cellulosic and lignocellulosic materials, which can be used as a growing medium alone or mixed with straws to grow and produce many types of edible mushrooms **(Ayilara *et al*., 2020 and Blasi *et al*., 2023)**.

Cardboard is a thick sheet of paper that is mainly used for packaging purposes. Cardboard is the last stage in papermaking technology, which prevents it from being recycled and used in papermaking. In Iraq alone, an estimated 5,446,000 tons of solid waste is generated annually, of which about 12.3% is incinerated according to 2005 statistics **(United Nations Statistics Division, 2011)**.

Due to the accumulation of this paper waste in offices, warehouses or streets and its environmental impact on society and to achieve sustainable development goals, our study aimed to evaluate the effect of different types of damaged paper on the productivity of the oyster mushroom *Pleurotus ostreatus*.

2. Methods

2.1. Collecting and Preparing Agricultural Substrates

Damaged paper was collected from the Northern Technical University offices in Mosul city and divided into three treatments (A4 printing paper, cardboard paper, and a combination of A4 printing paper and cardboard) The paper was cut into pieces of approximately 5-7 cm in size to increase the surface area for mushroom growth. They were soaked in tap water for 24 h to reach 60-70% moisture content, then sterilized at 121°C for 1 h (using a steam sterilizer) to eliminate any other microbes present **(Sufian *et al*., 2021; Getachew *et al*., 2019 and Al-Dulaimi *et al*., 2024)**, then left to reach room temperature in sterile conditions to prevent contamination.

2.2. Mushroom inoculum preparation

Oyster mushroom inoculum was pre-prepared on sterilized wheat grain obtained from the laboratories of the Department of Plant Production Technologies at the Agricultural Technical College.

2.3. Inoculation of Substrates

Oyster mushroom inoculum was mixed into the raw materials (damaged paper) sterilized at 5% (w/w) **(Kopiński and Kwiatkowska-Marks, 2012)**, packed in 1 kg perforated sterile plastic bags so that gas exchange could occur and the treatments were applied as follows:

I: Printing Paper A4 (100%)

II: Cardboard Paper (100%)

III: Combination of (A4 paper 50% + cardboard 50%).

The bags were placed in dark rooms with a high relative humidity of 80%, a temperature of 25°C, and an incubation period of 3-4 weeks for the fungus to fully colonize the soil. After the end of the incubation period, the bags were opened and placed in dim light (12 h light/12 h dark) to stimulate the formation of fruiting bodies. High humidity of 85-90% and good ventilation were maintained to minimize the CO2 concentration in the environment **(Girmay *et al*., 2016 and Saputera *et al*., 2020)**.

Fruiting bodies are monitored daily until they reach the desired harvest size. They are carefully hand-picked to avoid damaging them and to stimulate their growth in a second batch **(Grimm *et al*., 2016)**.

2.4. Measurements and Evaluation

Productivity: Weights of harvested fruiting bodies were collected after each harvest and calculated as wet weight per fruiting body (g) derived from the total wet weight of the culture medium **(Desisa *et al.*, 2024)**.

Biological efficiency: Calculated as follows:

Biological efficiency (%) = (fruit body wet weight (g)/planting medium dry weight (kg)) × 100 **(Yang *et al.*, 2013)**.

Quality assessment: Size: Measurement of the diameter of the fruiting body, Color: Evaluation of color using a colorimeter, Texture: Evaluation of hardness and durability **(Aditya *et al.*, 2024).**

2.5. Statistical Analysis

Data were calculated using SAS (2003) software and tested for significance using Duncan's multiple range test with the 1955 model to determine the significant difference between treatments at the probability level ($P \leq 0.05$).

3. Results and Discussion

The results of Figure 1 showed that there were significant differences in the average weights of the resulting fruiting bodies within these treatments at the 5% level. The paper mix treatment gave the highest yield of oyster mushrooms, with an average fresh weight of fruiting bodies of about 500 g/kg of medium, followed by the rest of the treatments. The high productivity of the paper mix is based on its high content of cellulose and lignin, which are highly active for fungal growth **(Delgado *et al.*, 2024)**. The cardboard treatment came second with an average fresh weight of fruiting bodies of about 430 g/kg of culture medium. Since cardboard has a nutrient-rich composition of the medium, it allows the fungi to be stronger **(Pouris *et al.*, 2024)**. On the contrary, the A4 paper treatment has lower productivity with an average fresh weight of about 380 g/kg of culture medium. This may be due to its relatively low nutrient content compared to cardboard **(Siroli *et al.*, 2017)**. The reason for the increase in production for the composite mix treatment may be because degradation occurs between the two, providing the best conditions under which the fungus can utilize the culture medium **(Dos *et al.*, 2022 and Abdullah and Al-Dulaimi, 2024)**.

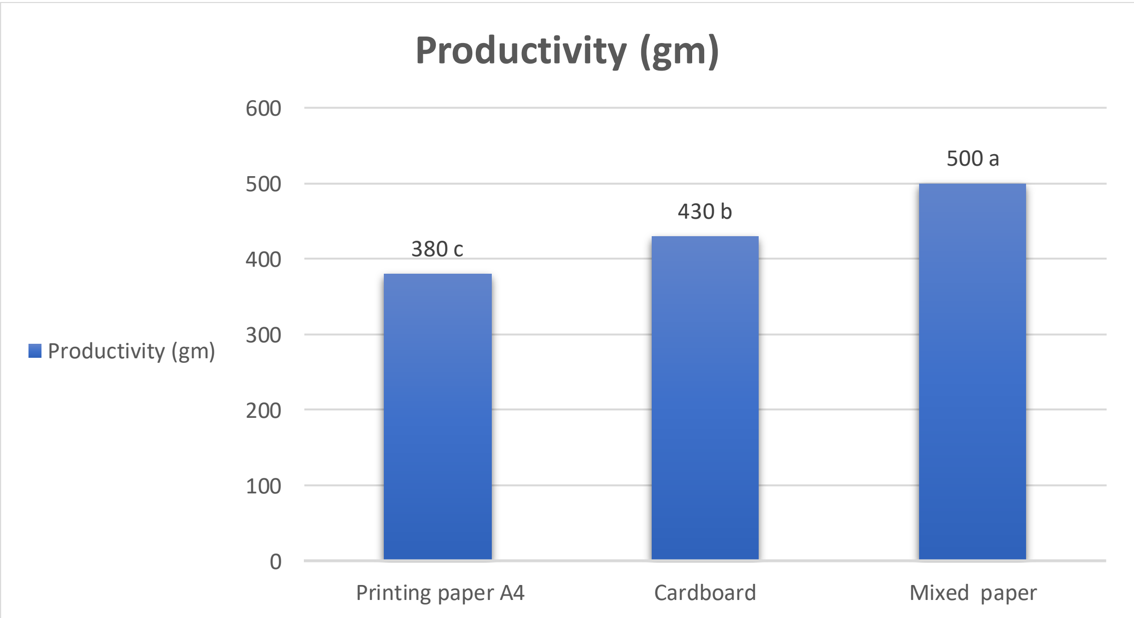

Figure (1). The effect of damaged paper on the productivity of oyster mushrooms

Figure (2). Oyster mushroom production stages, a- Mushroom inoculum preparation, b- Growth of Mushroom inoculum, c and d- Growth of Mushroom inoculum on Papers, e- Production of adult oyster mushrooms.

The results in Figure 3 showed significant differences at the 5% level. The highest bio efficiency was recorded for the paper blend treatment, which was 79%. This high efficiency can be explained by the high content of nitrogen, cellulose, and lignin in the paper mix, which are generally considered favorable energy sources for fungal growth **(Andlar *et al.*, 2018)**. The cardboard treatment comes second with about 74% bio efficiency because it has an optimal ratio of nutrients to support good fungal growth **(Fang *et al.*, 2023)**. The biological efficiency of the A4 paper treatment was around 70% due to its lower nutrient content than cardboard **(Yadav *et al.*, 2024 and Saadallah *et al.*, 2023)**.

The results in Table 1 showed significant differences between treatments at the 5% level. The paper mixture and cardboard treatments produced relatively larger fruiting bodies (with average diameters of 12 cm and 9.7 cm, respectively) compared to the A4 paper treatment, due to their high content of cellulose and lignin, which are powerful sources of energy and nutrients required for fungal growth **(Wu *et al.*, 2023 and Kumla *et al.*, 2020)**.

The low nutrient content of substrates and the characteristic difficulty in decomposing their components limit the growth of fungi **(Naranjo-Ortiz *et al.*, 2019 and Chen *et al.*, 2024)**.

The color results of the fruiting bodies grown in all treatments showed bright white fruiting bodies of high quality. White color typically indicates good health and freedom from contamination of the fungi, increasing their market value **(Im *et al.*, 2024 and Lin *et al.*, 2020)**.

The results showed that the fruiting bodies produced by all treatments had a firm texture and were resistant to damage during harvest and storage. This occurs because the nutrients in the substrates were balanced enough to support the growth of strong, cohesive tissues **(Im *et al*., 2024 and Bhambri *et al*., 2022)**.

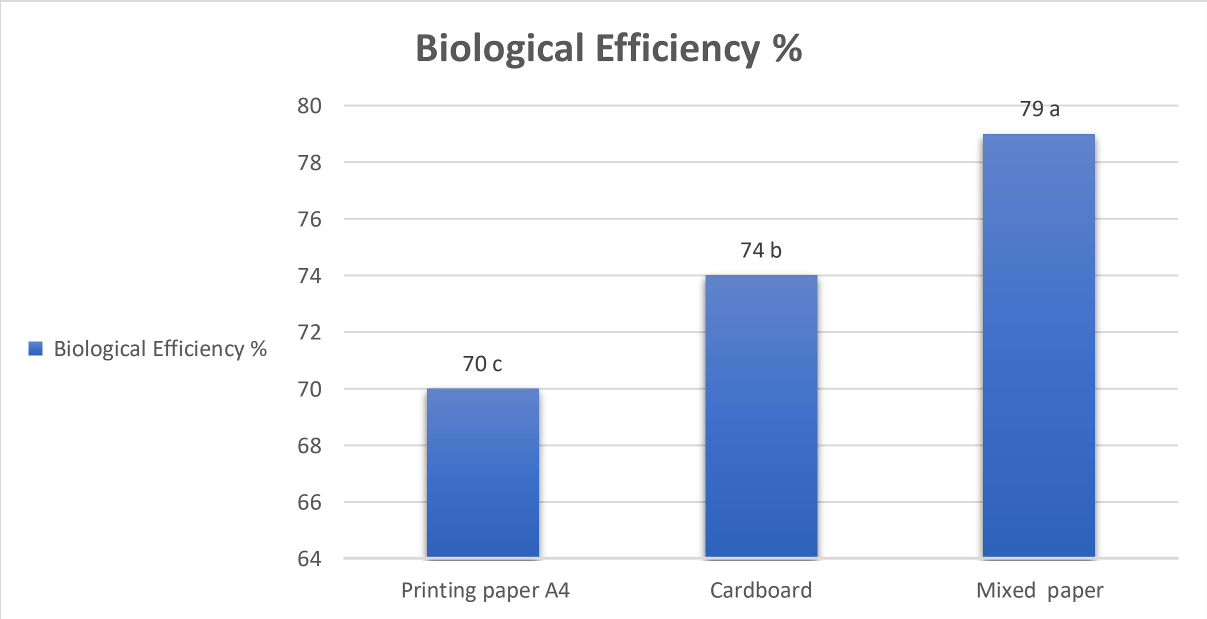

Figure (3). The effect of damaged paper on the Biological Efficiency % of oyster mushrooms

Table (1). Quality Evaluation of Oyster Mushroom Based on damaged Paper

Substrate	Size (average diameter/cm)	Colour	Texture
Printing paper A4	9.0 a	Bright white	Firm
Cardboard	7.6 b	Bright white	Firm and durable
Mixed paper	6.0 c	Bright white	Firm and durable

*Different letters in the same column mean significant differences at the 5% probability level.

4. Conclusions

Waste paper mix has proven to be the best medium for growing oyster mushrooms (*Pleurotus ostreatus*) due to its high productivity and high biological efficiency, thanks to its nutrient-rich nature (cellulose and nitrogen). The biological efficiency of oyster mushrooms increases with the higher nutritional composition of the substrate. This represents a means of protecting the environment and enhancing food security by recycling paper waste to produce high-quality food, including oyster mushrooms. This research demonstrates that future research focusing on culture media should focus on improving the use of low-efficiency media, especially waste.

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تقييم تأثير أنواع مختلفة من الورق التالف في إنتاج الفطر المحاري

أُجري هذا البحث في الكلية التقنية الزراعية/الجامعة التقنية الشمالية خلال شهر أبريل ٢٠٢٥، كان الهدف منه تقييم تأثير أنواع مختلفة من الورق التالف على إنتاجية فطر *Pleurotus ostreatus* ، جمعت الأوراق التالفة من مكاتب الجامعة التقنية الشمالية، وقُسِّمت إلى ثلاث معاملات (ورق طباعة A4 بنسبة ١٠٠%، ورق كرتون بنسبة ١٠٠%، وأوراق مختلطة من ورق طباعة A4 بنسبة ٥٠% وورق كرتون بنسبة ٥٠ %) ، أظهرت النتائج أن معاملة الورق المختلط أعطت أعلى إنتاجية للفطر بقيمة ٥٠٠ غم/كغم من الورق وبمستوى معنوي ٥% مقارنةً بالمعاملات الأخرى، تليها معاملة ورق الكارتون بتركيز ٤٣٠ غم/كغم ثم معاملة الورق A4 التي أعطت ٣٨٠ غم/كغم من الورق. سُجِّلت أعلى كفاءة بيولوجية في معاملة الورق المختلط (٧٩%)، يليها الورق الكارتون (٧٤%)، ثم ورق الطباعة (70%) أشارت الدراسة إلى أن نفايات الورق تعد الركيزة الأنسب لزراعة فطر المحاري ويسلّط هذا البحث الضوء على إمكانية استخدام نفايات الورق في زراعة فطر مستدامة، مما يسهم في الاستدامة البيئية والأمن الغذائي.