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Influence of Strain Variation and Growing Substrates on Productivity of the Button Mushroom (*Agaricus bisporus*)

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Abstract: This study was conducted in a private mushroom farm in Nineveh Governorate during 2024 to evaluate the effects of two strains of white button mushroom (*Agaricus bisporus*) grown on two cultivation media (grain straw and maize residues) and three concentrations of micronutrients (0,1, and 2 g L^{-1}). A Completely Randomized Design (CRD) with three replicates was used to arrange the experiment. The data obtained were statistically analyzed, and the means of treatments were separated according to Duncan's Multiple Range Test at a probability level of 0.05. level **(Al-Rawi & Khalafallah, 2000)**. The results indicated that the Dutch strain significantly surpassed the Indian strain in mycelial growth rate and number of fruiting bodies, producing the highest number of fruits per experimental unit (83). However, yield traits showed no significant differences between strains, although the Dutch strain recorded the highest total yield (13.6 kg. m^{-2}). Regarding growing media, the grain straw substrate achieved superior performance, producing the highest total yield (14.6 kg m^{-2}). Micronutrient supplementation, particularly at 2 g L^{-1}, significantly enhanced yield, reaching 14.3 kg m^{-2}. In terms of qualitative characteristics, the Dutch strain exhibited higher nitrogen content in fruiting bodies (647mg 100 g^{-1}). Analysis of cultivation media showed that the grain straw medium resulted in the highest nitrogen content (643mg 100g^{-1}). Furthermore, the application of micronutrients at 2g. L^{-1} significantly increased nitrogen content in fruiting bodies, reaching 700 mg 100 g^{-1}.

Key words: *Agaricus bisporus*, strains, micronutrients, grain straw, corn residues.

1. Introduction

Mushrooms (*Agaricus bisporus*) (lange) Imbach there are over 2,000 edible mushroom species, 200 of which are used in human food, and 30 of which are cultivated commercially. *Agaricus bisporus* is the most widely produced mushroom, accounting for 32% of global production of cultivated edible mushrooms، Mushrooms rank fourth among vegetables in terms of production, after potatoes, tomatoes, and lettuce. **Singh and Singh (2005)** stated that mushrooms are a source of protein for humans, especially in some developed countries where they can replace meat. Every 100 grams of dry weight of white mushrooms contains 84.33 grams of protein, 46.17 grams of carbohydrates, and 2.39 grams of fat. It also contains minerals, including 9 mg of calcium, 20.8 mg of copper, 3 mg of sodium, 4800 mg of potassium, and 48 mg of iron,(**Kurbanoglu *et al*., 2002)**. in addition to a large number of vitamins. *Agaricus bisporus* is considered the most important type of cultivated edible mushroom, followed by oyster mushrooms. It is commercially grown on sterilized and pasteurized wheat straw, with a final carbon to nitrogen ratio ranging between 12 and 13 **(Sánchez *et al*., 2001)**. Mushroom strain selection is of paramount importance, as genetic and agronomic characteristics are crucial in determining the nutrient requirements for mycelial growth and fruiting body yield. Recent studies have shown that mushroom morphology and yield can vary by up to 30% depending on the strain used **(Singh *et al*., 2020) and (Idrees *et al*., 2019)**, Growing edible mushrooms using agricultural waste as a growing medium contributes to the breakdown of lignin and cellulose. It also works to convert these wastes into edible bio-protein. There are also differences between strains in their growth rate and productivity of fungal bodies. The efficiency of mushroom growing media can be improved by using micronutrient) **Al-Allaf *et al*., 2026)**. These traits are critical for marketing the final product, particularly as they influence mushroom size, weight, and classification **(Wieme *et al*., 2022 and Banasik *et al*., 2019)**. Different strains may also exhibit varying degrees of disease resistance **(Muhammad *et al*., 2019)** and produce varying amounts of protein and enzymes. Fungi appear to be the key agents in the degradation of cellulosic lignin, through the production of hydrolytic and oxidative enzymes. Hydrolytic enzymes (cellulase and hemicellulase) are known for their ability to break down polysaccharides, while oxidative enzymes (ligninase) modify and degrade lignin. The current findings suggest the potential for utilizing industrial agricultural byproducts in the production of cellulosic lignin enzymes by fungi. However, variations in the composition of the byproducts and the types of fungi affect enzyme production. Therefore, further studies are needed to determine the optimal conditions substrates, **(Harfi *et al*., 2021)** Different mushroom species and the carbon-to-nitrogen ratio of the substrate are crucial factors affecting mushroom production and chemical composition. The improvement in yield and nitrogen content observed in this study may be attributed to enhanced nutrient availability, which is consistent with previous findings highlighting the role of biological and alternative fertilization strategies in improving crop performance **(Mustafa *et al*., 2026)**. Industrial agricultural waste has a low nitrogen content, so it is usually mixed with other nitrogen sources. Selecting the right substrate and mushroom species is essential for achieving maximum yield. **(Sebaaly *et al*., 2018)** indicated that alternative media based partially or entirely on chicken manure and winery waste are effective in producing good mushroom yields. This leads to the optimal use of local agricultural residues to improve mushroom yields in terms of both quantity and quality, providing the necessary nutrients for vegetative growth and surrounding soil that offers suitable physical, chemical, and biological conditions **(Kaur and Rampal, 2017).**

2. Materials and Methods

Experimental Site: The experiment was conducted in the production units of a pilot mushroom cultivation project located at a private farm in Nineveh Governorate during the 2024 growing season. Environmental conditions within the cultivation facility were maintained according to standard requirements for button mushroom production.

Strain Activation: Two strains of *Agaricus bisporus* (Lange) Imbach, namely the Dutch and Indian strains, were used in this study. Pure cultures of both strains were activated under controlled laboratory conditions prior to inoculation to ensure viability and uniform mycelial growth.

Spawn Preparation: Spawn was prepared using sterilized wheat grains as a carrier medium. The grains were cleaned, soaked, and sterilized, then inoculated with actively growing mycelium of each strain under aseptic conditions. The inoculated grains were incubated until complete colonization was achieved and the spawn was ready for use in the cultivation experiment.

Substrate Preparation and Composting Procedure

The cultivation substrate was prepared according to the method described by **Bahi (1984)** with minor modifications. The basal mixture consisted of 100 kg of lignocellulosic materials (grain straw and yellow corn residues), 600 kg of poultry manure, and 25 kg of wheat bran. In addition, mineral supplements were incorporated, including 5 kg of calcium ammonium nitrate and 30 kg of calcium sulfate. In the first phase, all components—except calcium sulfate—were thoroughly moistened and mixed, then formed into a compost pile measuring approximately 1.7 m in height and 1.5 m in width, while the length varied depending on the total quantity of prepared substrate. The composting process lasted 16–18 days, during which the pile was turned every three days to ensure proper aeration and uniform decomposition. Calcium sulfate was added on the twelfth day based on fermentation temperature monitoring. During composting, internal pile temperature reached 60–70 °C, indicating active microbial fermentation and proper compost maturation. In the second phase, the fermented substrate was transferred to a pasteurization chamber where steam was introduced, and filtered air was supplied at a rate of 200 m^3 ton^{-1} h^{-1}. The temperature was gradually increased to 58–60 °C and maintained for 5–7 days to complete pasteurization. On the final day, the substrate temperature was reduced to approximately 25 °C, rendering it suitable for inoculation and mushroom cultivation **Sanchez *et al*. (2001)**.

Spawning Stage : The prepared substrate was filled into nylon bags (50 × 90 cm), each containing approximately 10 kg of compost. Spawning was carried out at a rate of 1–1.5% (w/w) using grain spawn, applied in a layered method. A layer of substrate was first placed in the bag, followed by a uniform distribution of spawn, then successive alternating layers of substrate and spawn were added until filling was complete. The inoculated bags were incubated at 24 ± 1 °C and relative humidity of 85 ± 5% to promote mycelial colonization.

Casing Stage :After complete colonization of the substrate surface by the mycelium, a casing layer was applied using a commercially available peat-based substrate (Pindstrut Plus, Netherlands). The casing layer was maintained at a thickness of approximately 3–4 cm. During this stage, micronutrients were applied in solution form to the experimental units at concentrations specified in the experimental design. Yield.

The development of fruiting bodies begins about 14 days after covering, where the fruiting bodies turn into small fruits, which are called buttons at this stage. After 3-5 days, they develop into mature fruiting bodies, and they are picked and collected, and the required yield measurements are carried out on them.

Experimental Treatments and Statistical Analysis The experiment included the study of three factors:

1. Strain

This included two strains of the white sprouting mushroom, Agaricus bisporus, a Dutch strain and an Indian strain, which were prepared in the mushroom cultivation laboratory of the Faculty of Agriculture.

2. Type of culture medium

This involved the use of two culture media for culturing the white sprouting mushroom. The substrate material used in this experiment was [substrate material name missing]. The study included the following growing media:

A. **Grain Straw**: Wheat and barley straw, 15-20 cm long and freshly harvested from the previous wheat season, was used without grinding.

B. **Corn Residue**: The second material used in the study as the primary growing medium was corn residue from the 2023 autumn harvest. Micronutrient fertilization: Add micronutrients in solution form (product from a Spanish company) at a rate of 200 cm^3 using three concentrations:

1. Control. 2. 1 g/L. 3. 2 g/L

Experimental Design and Treatment Structure

Micronutrient solutions were applied after covering the substrate surface with the casing layer. The study evaluated three experimental factors: two strains of Agaricus bisporus, two cultivation media, and three micronutrient concentrations. The experiment was arranged according to a Completely Randomized Design (CRD) in a factorial arrangement (2 × 2 × 3), resulting in 12 treatment combinations, each replicated three times. Experimental units consisted of nylon bags measuring 50 × 90 cm, each containing approximately 10 kg of substrate. Treatments were randomly assigned to experimental units according to the specified design. Data obtained from the measured parameters were subjected to statistical analysis, and treatment means were compared using Duncan's Multiple Range Test at the 5% probability level **(Al-Rawi and Khalafallah, 2000)**.

Chemical Characteristics of the Cultivation Substrate

Samples were collected from the prepared cultivation substrate after compost maturation and prior to inoculation. The following chemical analyses were conducted:

Nitrogen Content (g kg^{-1})

Total nitrogen content of the substrate was determined using the Micro-Kjeldahl method, employing a micro-Kjeldahl apparatus according to standard analytical procedures.

Carbon to Nitrogen Ratio (C/N Ratio)

Carbon content was estimated indirectly by determining ash content. One gram of oven-dried substrate sample was combusted in a muffle furnace at 500 °C for 3 h. After cooling in a desiccator, the sample was weighed to determine ash weight. Organic matter content was calculated from weight loss during combustion, and carbon content was subsequently estimated using the standard conversion equation. The C/N ratio was then calculated based on the determined carbon and nitrogen values.

Carbon Determination and C/N Ratio Calculation

Carbon content was calculated based on the loss in weight after ignition according to the following equation:

Carbon weight (g) = Dry weight of substrate sample (g) − Ash weight (g)

The carbon-to-nitrogen ratio (C/N ratio) was then calculated using the following formula:

C/N ratio = Carbon content / Nitrogen content

Table (1). Chemical Analysis of Agricultural Media

Elements	Agricultural circles	
	Grain straw	Corn waste
	17.71	16.3
Nitrogen mg/kg	11.6	9.6
Phosphorus mg/kg	1600	900
Potassium mg/kg	17	21
C/N ratio before planting	29.1	33.7
C/N ratio after harvest	26	34
% of dry matter	6.8	6.5
Ash g	6.9	7
PH	423	474
Fe mg/kg	6900	5600
Na mg/kg	10.18	8.9
Ec mIU/cm³	17.71	16.3

The chemical analysis was carried out in the laboratories of the University of Mosul.

Dry matter content: 100g of mushroom culture medium was taken and dried in a drying oven at 72°C until the weight stabilized, and the percentage of dry matter in the mushroom culture medium was extracted from it.

Mycelial growth rate (mm day^{-1}) : The rate of mycelial growth was determined for the three culture media used in the study and for the three strains by culturing them in 250 ml glass bottles, 15 cm high and 5 cm in diameter. Five grams of mushroom spawn were placed at the bottom of the bottle, which was then filled with the culture media. The culture media was mixed with the studied strains, and the bottles were incubated at a specific temperature. At 25°C and 85% humidity, after 21 days from the start of cultivation, readings were recorded showing mycelium growth to the top of the bottles and calculated as (mm/day).

Soft Growth Characteristics: Fruit Body Fresh Weight (cm^3) The fruiting body weight of the mushroom was calculated by taking five complete fruiting bodies, weighing them, and taking the average. Yield Traits: Estimate the weight of the early yield by weighing the first and second pounds.

Nitrogen content of the fruit (mg/100g): Take 0.4 g of dry matter per experimental unit and grind it. Digest the samples until they become clear. Take 5 ml of the sample and measure the nitrogen using a microkaldal apparatus.

3. Results and Discussion

Mycelium growth rate (mm/day): Statistical analysis of The data shown in Table (2) indicates that the Dutch strain significantly outperformed the Indian strain in mycelial growth rate, recording 3.87 mm day^{-1} compared with 3.73 mm day^{-1} for the Indian strain. Regarding cultivation media, the grain straw substrate showed clear superiority over the corn residue medium, with mycelial growth reaching 3.51 mm day^{-1}, whereas the lowest growth rate (2.18 mm day^{-1}) was observed in the corn residue medium.

Table (2). Effect of strains, culture media and interaction coefficients between them on mycelium growth rate mm/day

Strain	**Medium**		**Medium impact strain**
	Corn residue	Grain straw	
Dutch	3.81 a b	4.01 a	3.87 a
Indian	3.03 b	3.61 b	3.73 a
Influence of the medium	2.18 b	3.51 b	

The interaction between strain and growing medium revealed significant differences. The highest mycelial growth rate (4.01 mm day^{-1}) was obtained from the interaction treatment of the Dutch strain grown on grain straw medium, while the lowest value (3.03 mm day^{-1}) was recorded for the Indian strain cultivated on corn residue medium. The superior performance of the Dutch strain may be attributed to genetic variation among strains, reflecting differences in their genetic constitution. Commercial mushroom strains are typically developed through successive breeding, selection, and hybridization programs aimed at improving growth efficiency and productivity. In addition, substrate composition plays a crucial role; the relatively higher nitrogen content and lower C:N ratio of the grain straw medium likely promoted faster mycelial colonization. These findings agree with previous reports indicating that mycelial growth rate varies depending on substrate type. **Wakchaure (2016)** Moreover, the enhanced growth observed in the grain straw medium may also be related to its electrical conductivity (EC) values, as lower salinity levels are known to favor mycelial development. This observation supports earlier findings that reported an inverse relationship between substrate salinity (EC) and mycelial growth rate **(Pema *et al.*, 2023).**

Number of fruits per unit area: Table (3) shows that the number of fruits per unit area in the Dutch variety was significantly higher, reaching (83) fruits compared to the Indian variety, which yielded (60) fruits.

Table (3). The effect of strains, growing media, micronutrients and their interaction coefficients on the number of fruits per experimental unit

Strain	Agricultural medium	Concentrations of micronutrients g/L			Strain × Cultivation medium	impact strain
		0	1	2		
Dutch	Grain straw	89 a	91 a	97 a	92 a	83 b
	Corn residue	60 c	77 b	87 a	69 c	
	Dutch Strain × Micronutrients	74 b	84 a	92 a		
Indian	Grain straw	56 d	62 c	71 b	63 c	60 c
	Corn residue	54 d	57 d	62 c	58 d	
	Indian Strain × Micronutrients	55 c	59 d	66 c	Grain straw	77 b
Effect of microelements		65 c	71 b	79 b	Corn residue	63 c

Treatments that share the same letter within each factor or within their interaction indicate no significant differences among them according to Duncan’s Multiple Range Test at the 5% probability level.

The growing medium showed significant differences in the number of fruits per unit area, with the grain straw growing medium giving the highest significant increase, estimated at (77) fruits. The data in the table itself show the effect of micronutrient treatment concentrations on the number of fruits per unit area. The micronutrient spray treatments led to an increase in the number of fruits per unit area, and the highest number of fruits was significantly found in the 2g micronutrient treatment, with production reaching (79) fruits per unit area, while the lowest number was observed in the control treatment, which yielded (65) fruits. As for the bilateral interaction coefficients between the strain and the growing medium in this trait, it is noted from Table (3) that the highest number of fruits (92 fruits) resulted from the interaction treatment between the Dutch strain and the growing medium of grain straw, while the lowest number of fruits (58 fruits) was in the interaction treatment between the Indian strain + the growing medium of corn residues. Regarding the effect of the binary interaction between strain and micronutrient concentrations on the number of fruits, the highest number of fruits (92) resulted from the interaction between the Dutch strain and a concentration of 2 g/L of micronutrients. Conversely, the lowest number of fruits (65) per unit area was observed in the interaction between the Indian strain and a concentration of 0 g/L of micronutrients. The results in the same table indicate the effect of the three-way interaction of the studied factors on the number of fruits. The interaction treatment between (Dutch variety + grain straw growing medium + spraying with a concentration of 2 g micronutrients/L) gave the highest number of fruits, reaching (97) fruits per unit area, while the lowest number of fruits (54) fruits was found in the three-way interaction treatment (For the Indian strain + growing medium: corn residues + treatment with a concentration of zero grams of micronutrients/liter). The difference in the number of fruits in the breeds may be due to the difference in the genes that control this trait, genetic factors. The difference and superiority of the Dutch breed in the number of fruits trait may be explained by the difference in the components of the growing media and their content of mineral elements. Table

(1) The results are consistent with what **Zied *et al*. (2018)** stated, namely that fungal strains are affected by the physical, chemical, and microbiological components and composition of the culture medium, which may lead to the promotion or inhibition of fruiting body primordia **(Uddin *et al*., 2013)**.

Table (4). The effect of strains, growing media, micronutrients and their interaction coefficients on the total yield per unit area (kg/m^2)

Strain	Agricultural medium	Concentrations of micronutrients g/L			Strain × Cultivation medium	Medium impact strain
		0	1	2		
Dutch	Grain straw	13.3 b	15.4 a	17.6 a	15.4 a	13.6 b
	Corn residue	10.8 c	10.9 c	13.8 b	11.8 c	
	Dutch Strain × Micronutrients	13.5 b	14.6 b	16.6 a		
Indian	Grain straw	13.7 b	13.8 b	15.6 a	14.3b	13.5 b
	Corn residue	8.3 d	12.6 c	10.3 d	12.7 c	
	Indian Strain × Micronutrients	9.5 d	11.7 c	12.0 c	Grain straw	14.8 a
Effect of microelements		11.5 c	13.1b	14.3 b	Corn residue	12.2 b

Treatments that share the same letter within each factor or within their interaction indicate no significant differences among them according to Duncan's Multiple Range Test at the 5% probability level.

Total yield per unit area (kg/m^2)

It is noted from Table (4) that there are variations between the strains in the total yield of white mushrooms (kg/m^2). The Dutch strain significantly outperformed the Indian strain, and gave a total yield of 13.6 kg/m^2. As for the effect of growing media on the yield of fungal fruiting bodies, it is noted that the growing medium of grain straw was significantly superior, as it gave the highest total yield of 14.8 kg/m^2 compared to the growing medium made of corn residues, which yielded 12.2 kg/m^2. Regarding the effect of micronutrients on this trait, the same table shows the significant superiority of the 2 g/L micronutrient treatment in producing the highest total yield of fungal fruiting bodies, reaching 14.3 kg/m^2. Regarding the effect of the bilateral interaction coefficients between the strain and the medium, it is evident from Table (4) that the interaction coefficient between the Dutch strain and the growing medium consisting of grain straw gave the highest total yield of 15.2 kg/m^2, and the lowest total yield recorded in the interaction coefficient between the Dutch strain and the growing medium consisting of corn residues was 11.8 kg/m^2. Regarding the interaction between strains and micronutrients in total yield, the interaction between (Dutch strain + high concentration of micronutrients) was significantly different, with a yield of 16.6 kg/m2, while the lowest total yield was 9.5 kg/m^2. Regarding the three-way interaction between strains, growing medium, and micronutrient spraying on total yield, the interaction treatment (Dutch strain + grain straw + high concentration of micronutrients) was significantly superior, with a yield of 17.6 kg/m^2. This may be due to the fact that the Dutch strain was superior in mycelium growth rate (Table 2) and required fewer days for the emergence of fruiting bodies (Tables 3). The superiority of the grain straw culture medium may be attributed to its mineral content, including nitrogen (Table 1), which plays a role in protein and amino acid synthesis. These results are consistent with the findings of [the study/research]. **(Pardo-Giménez *et al*., 2016)**. The superiority of treatment with high concentrations of micronutrients in yield may be due to the role of micronutrients, including iron, in activating several enzymes such as nitrate reductase and nitrogenase, which leads to accelerating the processes of building and growth. Iron also plays a role in activating the formation of fruiting bodies and accelerating the development of fruiting bodies into fruiting bodies **(Diego *et al*., 2018)**. This leads to a reduction in the time required for the formation of fruiting bodies (Tables 3).

Nitrogen content of the fruiting body (mg/100g): The results in Table (5) indicate the effect of strains, growing media and micronutrients on the nitrogen content of the fruiting body of the mushroom. It is noted that there are no significant differences between the strains in this characteristic, as the Dutch strain gave the highest value of 647 mg/100g and the lowest value of the nitrogen content of the mushroom fruits was for the Indian strain, 634 mg/100g. As for the effect of the growing media on the nitrogen content of the fruiting bodies, the results indicate that there are no significant differences between the two growing media under study in the nitrogen content of the mushroom fruiting body. Regarding the effect of micronutrient treatment on this trait, the same table shows that increasing the concentration of micronutrients led to a significant increase in the nitrogen content of the fruiting body. The highest concentration, 2 g/L, resulted in the highest nitrogen content in the fruiting bodies of the fungus. The concentration of micronutrients did not differ significantly with 1 g/L, which recorded (700) mg nitrogen/100 g, compared to the control treatment (without adding micronutrients), which recorded the lowest nitrogen content for the fruiting body, amounting to (593) mg nitrogen/100 g The results of the interaction between strain and growing medium on fruit body nitrogen content indicate no significant differences between treatments in fruit body nitrogen content, with the highest nitrogen content recorded in the treatment combining the Dutch strain and the grain straw growing medium The nitrogen content in the fruit reached 679 mg/100 g, while the lowest nitrogen content in the fruit was 607 mg/100 g in the treatment combining the Indian strain with the grain straw growing medium.

The results of the effects of the dual interaction between strain, growing medium, and micronutrients on the nitrogen content of the fruit indicate that ‹The interaction treatment between the Dutch strain and micronutrients at a concentration of 2 g/L was significantly superior, with the fruit body nitrogen content reaching 725 mg nitrogen/100 g, while the lowest nitrogen content in the fruit body was 592 mg nitrogen/L As for the effect of the interaction between strains, growing medium and micronutrients on this trait, the fruiting bodies resulting from the Dutch strain with the growing medium of grain straw and a concentration of 1.5g of micronutrients/L gave the highest significant nitrogen content of 738mg nitrogen/100g, while the lowest nitrogen content of 554mg/100g was recorded in the interaction treatment between the Dutch strain. With corn residues, zero trace elements/liter.

Table (5). Shows the effect of strains, growing media, micronutrients and the interaction coefficients between them on the nitrogen content of the fruit body mg/100 g

Strain	Agricultural medium	Concentrations of micronutrients g/L			Strain × Cultivation medium	Medium impact strain
		0	1	2		
Dutch	Grain straw	631 b	670 b	738 a	679 b	647 b
	Corn residue	554 c	583 c	712 a	616 b	
	Dutch Strain × Micronutrients	592 c	626 b	725 a		
Indian	Grain straw	576 c	610 b	635 b	607 b	634 b
	Corn residue	611 b	685 b	716 a	661 b	
	Indian Strain × Micronutrients	593 c	647 b	675 b	Grain straw	643 b
Effect of microelements		593 c	636 b	700 a	Corn residue	638 b

Treatments that share the same letter within each factor or within their interaction indicate no significant differences among them according to Duncan’s Multiple Range Test at the 5% probability level.

The differences in the fruit body's nitrogen content in the strains may be attributed to the differences in the genetic structures of the strains, which differ in their metabolic efficiency and absorption of elements. It is affected by environmental conditions such as humidity, temperature, and CO_2 concentration. It is also affected by the contents of the growing medium, the availability of elements for absorption, and the pH of the medium and Ec. The results are consistent with the findings of **Andrade *et al*. (2010)** and **Vetter (2003)**, who noted differences in the mineral content of the fungus's fruiting body among the different strains.

The superiority of the grain straw culture medium, exhibiting the highest nitrogen content in the fruiting body, may be attributed to its lower potassium content (Table 1). Similarly, the decrease in salinity (Ec) led to increased nitrogen absorption and accumulation in the fruiting body of the fungus **(Griensven and Roestel, 2004).**

The addition of micronutrients may stimulate and improve fungal growth due to iron's role in various oxidation-reduction and respiration processes, as well as its involvement in enzyme synthesis. This leads to increased metabolic activity in the fungus and greater absorption and accumulation of nutrients in its various parts, including the fruiting body The fruiting body of the mushroom **(David *et al*., 2005)**.

Table (6). Shows the effect of strains, growing media, micronutrients and their interaction coefficients on the iron content of the fruit body (mg/100 g)

Strain	Agricultural medium	Concentrations of micronutrients g/L			Strain × Cultivation medium	Medium impact strain
		0	1	2		
Dutch	Grain straw	38.3 d	43.5c	51.6 b	44.4 c	43.6 c
	Corn residue	36.9 d	40.8 c	50.9 b	42.8 c	
	Strain × Micronutrients	37.6 d	42.1 c	51.2 b		
Indian	Grain straw	37.1d	42.3 c	60.5 a	46.6 c	46.9 c
	Corn residue	37.8 c	39.9 c	64.2 a	47.3 c	
	Strain × Micronutrients	37.4 c	41.1 c	62.3 a	Grain straw	56.0 b
Effect of microelements		37.5 c	41.6 c	56.7 b	Corn residue	44.5 c

Treatments that share the same letter within each factor or within their interaction indicate no significant differences among them according to Duncan's Multiple Range Test at the 5% probability level.

Fruiting body iron content (mg/100g)

The results in Table (6) show that the fruiting body iron content was not significantly affected among the strains under study, and that the highest iron content in the fruiting bodies of the fungus (46.9) mg/100g was observed in the Indian strain. The same table also shows significant differences in the iron content of the fruiting bodies between the growing media used in the study, and the highest iron content of the fruiting bodies was (56.0) mg/100g in the growing medium of grain straw. As for the effect of micronutrients on this trait, it appears that increasing the concentrations of micronutrients used led to a significant increase in the iron content of the fruiting bodies, reaching 56.7 mg/100 g using the high concentration of micronutrients, compared to the lowest content (37.5) mg/100 g resulting from the treatment with zero concentration of micronutrients/liter. Regarding the results of the interaction between the strain and the growing medium on the iron content of the fruit bodies, it was observed that the interaction treatment between (the Indian strain and the growing medium of corn residues) recorded the highest increase in the iron content of the fruit body, reaching 47.3 mg/100 g, compared to the lowest iron content recorded in the interaction treatment between The Dutch strain and the corn residue culture medium recorded 42.8 mg/100g of iron content in the fruit.

The results of the binary interaction between strain and micronutrient concentrations indicate that the interaction between the Indian strain and the high concentration of micronutrients was significantly superior, recording a maximum iron content in the fruit of 62.3 mg/100g. The lowest iron content in the fruit bodies (37.4 mg/100g) resulted from the interaction treatment (Indian strain + no additive).

Regarding the effect of the three interaction treatments among the studied factors on the same trait, the results indicate a clear and significant increase in the iron content of the fruit bodies, reaching a maximum of 64.2 mg/100g in the interaction treatment. Between (Indian strain + corn residue growing medium + spraying with a concentration of 2 g micronutrients/L) and the lowest iron content recorded in the interaction treatment (Dutch strain + corn residue growing medium + no micronutrient addition) was 36.9 mg/100 g.

The variation in fruiting body content among strains may be attributed to differences in genetic makeup, as the fruiting body content of the fungus varies according to the strain. Strains also differ in their metabolic activity and absorption of elements. The results are consistent with what **Vetter (2003)** stated. The high iron content of the fruit body in the growing medium of grain straw residues may be attributed to the iron content of the growing medium of grain straw (Table 1), and the low iron content of the fruit body in the growing medium of corn residues may be attributed to the low iron content of the growing medium of corn residues. Also, the high acidity of the medium (Table 1) This may lead to weak growth and activity of the fungus, which in turn reduces the process of iron absorption, since iron absorption is active absorption. Also, the addition of chelated iron increases the fruiting body's iron content, as it is a compound readily available for absorption by the fungus more than other forms of iron. Thus, the fruiting body's iron content increases, and the results are consistent with what **David *et al*. (2005)** concluded.

3. Conclusions

Cultivating food mushrooms using nutritional deficiencies as a growing medium involves the breakdown of lignin and cellulose. It also works to convert these deficiencies into edible forms. There are differences between strains in their growth rate and productivity of fungal bodies. The growing medium can be enhanced by using small elements.

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تأثير اختلاف السلالات وبيئات النمو في إنتاجية الفطر البرعمي الأبيض(*Agaricus bisporus*)

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الخلاصة

أُجريت هذه الدراسة في مزرعة فطر خاصة بمحافظة نينوى خلال عام 2024 لتقييم تأثير سلالتين من الفطر البرعمي الأبيض (*Agaricus bisporus*) المزروعتين على وسطين للزراعة (قش الحبوب ومخلفات الذرة) وثلاثة تراكيز من العناصر الصغرى (0، 1، و2 غمL^{-1}) .تم ترتيب التجربة وفق تصميم كامل العشوائية (CRD) مع ثلاث مكررات. وقد تم تحليل البيانات إحصائياً وفصل متوسطات المعاملات باستخدام اختبار Duncan's Multiple Range Testعند مستوى دلالة 0.05 (الراوي وخلف الله، 2000). أشارت النتائج إلى أن السلالة الهولندية تفوقت بشكل معنوي على السلالة الهندية في معدل نمو الميسيليوم وعدد الأجسام الثمرية، حيث أنتجت أعلى عدد من الثمار لكل وحدة تجريبية (83 ثمرة). ومع ذلك، لم تُظهر خصائص المحصول فروقاً معنوية بين السلالتين، رغم تسجيل السلالة الهولندية لأعلى إنتاج كلي (13.6 كغ م$^{-2}$). فيما يخص وسائط الزراعة، حقق وسط قش الحبوب أداءً أفضل، حيث أنتج أعلى إنتاج كلي (14.6 كغ م$^{-2}$). وساهمت إضافة العناصر الصغرى، خصوصاً عند 2 غمL^{-1} ، في زيادة الإنتاج بشكل معنوي، ليصل إلى 14.3 كغ م$^{-2}$. أما بالنسبة للصفات النوعية، فقد أظهرت السلالة الهولندية محتوى أعلى من النيتروجين في الأجسام الثمرية (647 ملغ 100 غم$^{-1}$). وأظهر تحليل وسائط الزراعة أن وسط قش الحبوب حقق أعلى محتوى من النيتروجين (643 ملغ 100 غم$^{-1}$). علاوة على ذلك، أدت إضافة العناصر الصغرى عند 2 غم L^{-1} إلى زيادة معنوية في محتوى النيتروجين في الأجسام الثمرية، ليصل إلى 700 ملغ 100 غم$^{-1}$.

الكلمات المفتاحية : *Agaricus bisporus* ، السلالات، المغذيات الدقيقة، قش الحبوب، مخلفات الذرة، وسائط الزراعة، نمو الفطر.